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Demand for Precision

Since the last war, there has been introduced into foundry practice a number of processes, all of which, *inter alia*, bring about much greater dimensional accuracy in the casting as it leaves the foundry. Amongst these processes are shell moulding, investment casting (lost wax), the CO_2 process, and die-casting as applied to cast iron. Shell moulding is said to be practised in 1,000 foundries. One precision castings foundry—there are now many—which a year or two ago, had a staff of about 25, now employs 150. The output of cast-iron die-castings has assumed imposing proportions and recently it has been augmented by the production of cast-iron gutters in dies. Taken together, these precision-cast items must now be an important factor in foundry production, moreover, they are being delivered to a great variety of consumers.

It is thus pertinent to ask what will be the reaction of the foundries who have not so far taken up any of these new processes. In some cases, the answer is that they have had to provide themselves with more accurate patternplates and coreboxes and undoubtedly by this means they, too, will have attained closer dimensional tolerances for their production. Another impact has been the replacement of conventional die-castings by the products of the shell-moulding process, and this not on the grounds of increased dimensional accuracy, but on improved physical properties—especially internal soundness.

The major feature to be examined is the cumulative effect on the engineering industry of the receipt of ever-increasing quantities of castings showing much improved dimensional accuracy. At the moment, buyers are only receiving the smaller types of castings, but, according to the French, "appetite increases with eating," and they will soon be looking for decreased machining costs on the larger types they buy. In America, we learn, machine-shops calling for a regular supply of castings are providing themselves with their own shell-moulding outfit, this to our mind is a retrograde step, as it means the creation of hole-and-corner foundries but little receptive to progressive notions. Increasingly, the customer will be correlating his supply of castings with his machining costs and framing his buying policy on the results shown. Castings made by the newer processes will have to prove themselves able to attain standards other than merely reduced machining costs—such as, pressure-tightness, abrasion-, heat- and corrosion-resistance and suitability for surface treatment. We do not anticipate undue troubles in these directions, but new processes have to show themselves capable of meeting conditions in fields other than those in which they make their major appeal. One has only to refer to another comparatively new invention—spheroidal-graphite cast iron; initially, it made its appeal by its enhanced tensile properties, but it has taken much research to establish its electrical, magnetic, welding, machining, and a host of other properties. A few metallurgical disadvantages of the shell-moulding process have already come to light. There is for example the carbon pick-up when casting mild steel. Foundry technique, too, has had to be modified, and even the promised dimensional superiority has sometimes been vitiated by warping. Yet we feel sure that, with added experience, these early teething troubles will be finally overcome—as overcome they must be to meet what is bound to be an ever more-exacting market.

E

Correspondence

CO_2 PROCESS

To the Editor of the FOUNDRY TRADE JOURNAL

SIR,—We have read the letter from the Harborough Construction Company about the above process in your issue dated August 19, with considerable interest.

We have also been experimenting here with this process for some months, and the largest casting so far made was an iron casting weighing 11 tons, in which the centre core was made by the CO_2 process. This core was 21 in. dia. by 60 in. long and the section of metal round the core was 14 in. thick. We obtained an excellent strip with this core, with no sign of scabbing or burning on.

The heaviest steel casting so far produced was one weighing just over 3 tons, and this was 16-ft. long with a general thickness of 4½ in. The mould for this casting was completely made by the CO_2 process, and no moulding boxes or core irons were used. Here again, the strip was exceptionally good.

We feel that there are considerable advantages in this process of moulding, and we are still carrying out large-scale experiments with it.—Yours, etc.,

for Glanmor Foundry Company, Limited,
IVOR REES,
Foundry Superintendent.

Llanelly,
August 20, 1954.

German Foundrymen's Association

The annual meeting of the *Verein Deutscher Giessereifachleute* (German Foundrymen's Association) is to be held in Stuttgart from October 14 to 16. The general programme is to be:—

October 14, morning—works visits; afternoon—technical session; evening—Schlosskonzert (Castle Concert) at Ludwigsburg.

October 15, morning and afternoon—technical sessions covering pig-iron, steel-castings and malleable sessions in the large hall of the Kurhaus and non-ferrous castings and light-alloys in the small hall. Evening, social gathering at Killesburg.

October 16, morning, 45th annual general meeting and film show. The conference closes at 1 p.m.

Conference Paper Author

MR. S. TAYLOR, author of the paper "Production of Heavy Steel Castings," printed on page 229 of this issue, has had vast experience in foundrywork. In 1911 he joined the steel foundry department of Cammell, Laird & Company, Limited (now English Steel Corporation, Limited), and was employed in the patternshop until 1928. In 1928 he transferred to the production drawing office and finally to the foundry sales department. He returned to the foundry in 1934 as chief estimator and subsequently as assistant to the foundry manager in charge of process planning and estimating.

A.D.A. to Join C.I.D.A.

The council of the Aluminium Development Association has decided that an invitation should be accepted to join the *Centre International de Developpement de l'Aluminium*, which was set up some three years ago at the suggestion of the O.E.E.C. The C.I.D.A., which is constituted of five countries at present—France, Italy, Switzerland, Germany, and Austria—has the fundamental aim of furthering the future development of aluminium by discussing problems of common interest among the participating organizations.

The secretariat of C.I.D.A. is located in Paris, at the offices of l'Aluminium Français, under a governing committee, the chairmanship of which is held by M. Dumas of the same organization.

David Brown's S.B.A.C. Exhibits

Among the principal David Brown exhibits at the Society of British Aircraft Constructors exhibition at Farnborough from September 6 to 12, will be several interesting examples of aircraft steel castings produced by the centrifugal casting process for high-temperature service. Produced by the David Brown Foundries Company, of Penistone near Sheffield, these include gas-turbine components which, though large and complex, have relatively light sections, successful manufacture being achieved by means of the centrifugal-casting technique. The operating temperature for these items ranges from 650 to 900 deg. C. Other exhibits (Fig. 1) all of which are produced to Ministry of Supply (Air) specifications D.T.D. 666 and D.T.D. 705, include arrester hooks, wing fittings, engine mounting brackets, and clutch housings.

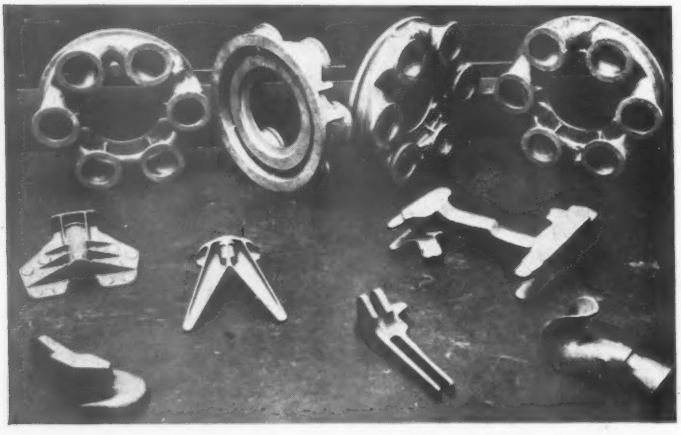


FIG. 1.—*Selection of aircraft-engine and airframe castings to be exhibited by the David Brown Foundries Company, Penistone, near Sheffield, at the S.B.A.C. exhibition.*

Production of Heavy Steel Castings*

By S. Taylor

In writing this short Paper the Author endeavours to portray to foundrymen, and particularly to those operating in a modest way, some idea of what an immense undertaking is the making of some of the world's largest steel castings.

Introduction

In this age of speed, high production and output, the designer directs his thoughts to still greater and heavier machines, plant, etc., in order to attain his ideals. A casual glance at modern rolling-mill units, the large forging and extrusion presses and the like, makes obvious the fact that the demand for still larger and heavier steel castings continues to grow and the steelfounder is being called upon to produce castings of a size and weight never before contemplated. The foundry with which the Author is associated, has been enlarged and modernized in order to make steel castings of up to 200 tons in weight. Prior to the last war, the largest steel castings made there were in the region of 120 tons, but in 1953 and 1954 the largest and heaviest steel castings ever made within the British Commonwealth were being produced. The record to date is held by press castings of 185 tons delivered weight, and arrangements for the handling of such an immense mass of steel between the various works departments provides many problems for the foundry staff. The mention of these problems gives one an opportunity to outline the procedure adopted in the successful production of 185-ton crosshead beams, the overall dimensions of which were 26 ft. 6 in. long, 13 ft. 6 in. deep and 8 ft. 6 in. wide.

* Paper presented to the fifty-first annual meeting of the Institute of British Foundrymen, held in Glasgow.

Process Planning

The making of large castings of whatever shape, size, or structure, always presents a variety of difficulties to overcome. Design, feeding, easing, contraction, etc., must be considered before a start can even be made on the pattern. Contraction is, and always will be, a controversial subject, and whilst no hard and fast rule can be laid down, experience has taught that in large press castings of a fixed wall structure, an allowance of 1 in 80 is a fairly safe contraction rule to which to work. For internal core dimensions, $\frac{1}{16}$ in. per ft. short of the 1 in 80 contraction is allowed on all lengths and widths, but

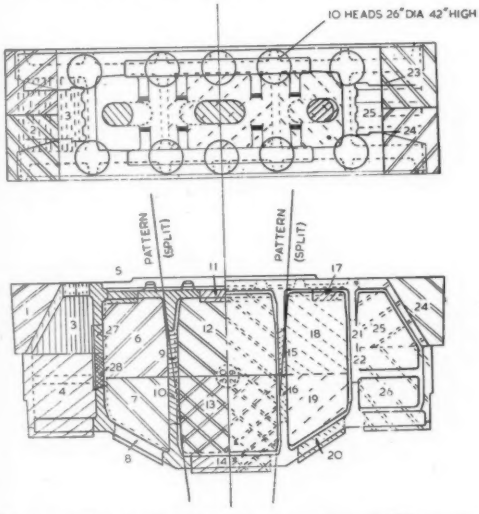


FIG. 1.—*Sketch showing the core layout* (30 *cores in all*) *for the cross-head beam casting.*

Separate coreboxes were required at the following positions: Box (1) 1, 2, 23 and 24; box (2) 3 and 25; box (3) 4 and 26; box (4) 7 and 19; box (5) 6 and 18; box (6) 13; box (7) 12; box (8) 8 and 20; box (9) 14; box (10) 5 and 17; box (11) 11; box (12) 21, 22, 27 and 28; box (13) 9, 10, 15 and 16; and box (14) 29 and 30.

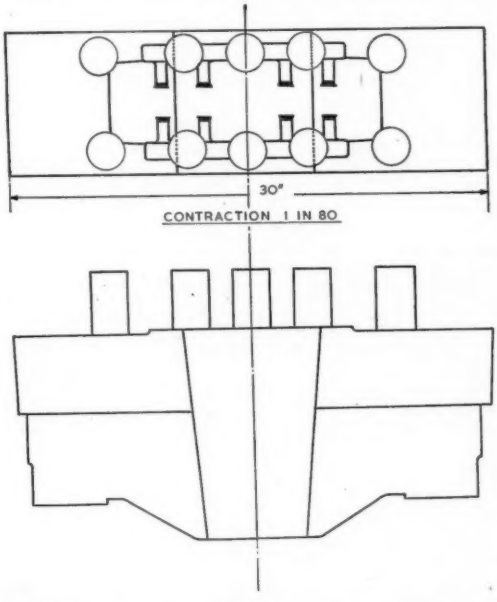


FIG. 2.—*Sketch indicating how the pattern was divided, and the positions of the feeder heads.*

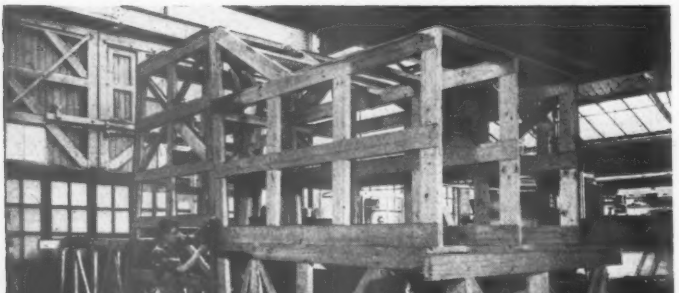


FIG. 3.—*Internal pattern structure for the 185-ton crosshead beam casting.*

the depth is kept to size. Drawings are prepared carefully, showing how the cores must be split for easy handling and stove drying, also the breaking-down of the pattern in order to facilitate handling and easy withdrawal from the mould, as shown in Figs. 1 and 2.

The method of feeding the casting is a most important factor. Feeder heads are carefully designed and placed over the heaviest sections, which in turn feed the thinner sections. Economy in the use of liquid steel must be borne in mind during this part of the process. As will be seen, ten feeder heads 26 in. dia. and 42 in. high were used for the job mentioned and the padding was designed in order to help in feeding the thicker sections.

The method of pouring and running of the casting was the next step to be decided upon, bearing in mind that the bulk of the steel would be conveyed to the mould in three large ladles each of approximately 70-tons capacity. It was, therefore, decided to run the steel down launders to each end of the mould and through a down-runner into the centre of the mould. The end ladles were carried by overhead cranes, and the centre ladle placed on a stand. Wooden models of the casting and the crane layout were made, to assist in the discussions of the methods to be used in the pouring and subsequent transporting of the casting. On each side of the casting, four large loops were incorporated, and their position carefully calculated and so designed for lifting the casting safely.

Patternmaking

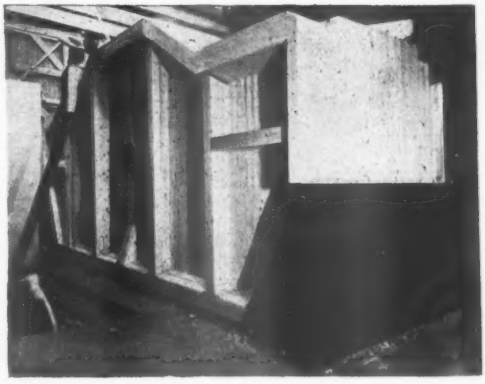
The pattern was strongly constructed, the body portion being made in five sections. Each section was designed for easy withdrawal from the mould and all the facings and flanges made to work in a "loose" manner from the body, as shown in Figs. 3 and 4. The coreboxes, also of strong construction, were made collapsible, or as the coremaker termed it, "stable-door" fashion, so as to provide for easy handling of the core materials. Approximately 1,350 cub. ft. of timber was used to make the pattern and coreboxes. In all, 14 coreboxes were needed to cover the range of 30 cores required. Ample taper was allowed on all sections of the pattern to permit easy withdrawal from the mould.

Moulding

The mould was made in a steel-lined pit, 32 ft. long, 18 ft. wide and 12 ft. deep. Moulding commenced with the preparation of a bed, made to the shape and contour of the bottom of the pattern. Rails were rammed-in across the bed, to be used for anchoring the large centre cores. All five pieces of the pattern were then assembled on the bed and firmly spragged to the pit sides in order to maintain rigidity whilst moulding was proceeding. The centre down-runner was fixed into position and the ramming up of the mould followed on. A layer of approximately 4 in. of "compo" (moulder's composition) was pegrammed up to the pattern face and then backed up with old moulding sand, as shown in Fig. 5. This "compo"—a very coarse-grained material made from crushed chamotte* and firebricks milled and bonded with 10 per cent. fireclay, the whole mixture

*Chamotte is a calcined bauxite clay, high in alumina. It is crushed into grades suitable for mixing in the "compo" and for making the paint for "finishing."

FIG. 4.—*Pattern almost completed for the crosshead beam (designed for a 35,000-ton press). It is 30 by 12 by 9 ft. overall.*



containing about 10 per cent. moisture—was specially prepared in a department adjoining the foundry. Although capable of being rammed hard, it retains its open-grained structure.

The top of the mould was made in two boxes, each measuring 16 ft. by 12 ft. by 4 ft. These top parts carry a great deal of reinforcement in the form of bars and lifters to enable the large volume of sand to be held firmly in position whilst the boxes are being transported about the foundry. After being rammed up, the top parts were lifted clear of the mould and supported on pedestals for overhead finishing prior to stove drying. The pattern having been withdrawn from the mould, the mould faces were painted and finished with chamotte paint.

This paint was firmly worked into the open-grained "compo" and a smooth surface was obtained. All overhanging mould faces were supported by firebricks and support bars were placed across the mould to prevent any sagging during drying, as shown in Figs. 6 and 7. After completing this finishing process, the mould was covered by cast-iron plates on which were placed eight portable coke-fired drying stoves, through which compressed air was blown into the mould. In this way, a continuous flow of hot air at 380 deg. C. was maintained, the drying process being carried out for three weeks continuously, until the mould faces were well-dried to a depth of 12 to 14 in.

During this time, the two top parts were painted with chamotte and finished off. They were then dried in coke-fired stoves for approximately 100 hr. at 400 deg. C. Good drying of the mould and top parts is an essential factor in ensuring a good strip during the cleaning of the casting.

Coremaking

The cores for heavy castings must be particularly strong to withstand the pressure of the liquid steel and to enable them to be lifted for drying and placing in the mould. As a reinforcement, large cast-iron grids were rammed up in the cores for the cross-head and, in order to keep them firmly in position, firebricks were placed in between the grids. The faces of the cores were made up of approximately 3 in. of rammed "compo," the centre of the cores comprising a large amount of coarse ashes to aid contraction during cooling, and to enable the gases created by the heat to escape from the cores to the vents provided in the mould.

Provision was also made in the cores for the anchor bolts required to fasten them down to the rails already in position in the bed of the mould. The cores were then coated with chamotte paint. It should be observed that the large centre cores, each weighing approximately 20 tons, were made in two pieces to facilitate drying, the halves being brought together in the mould by the anchoring bolts. All the cores were stove dried at a temperature of 400 deg. C. for 98 hr. Approximately 65 tons of "compo" were used in moulding and coremaking.

Closing and Binding

When the drying of the mould and the cores was completed, closing or setting of the cores began. The bottom cores were first fixed and anchored securely to the rails already provided in the bed. As all cores were placed in position, a very careful check was made on wall thicknesses by a patternmaker, as shown in Figs. 8 and 9. Thicknesses were kept to a minimum tolerance, as it was known that the casting would require the maximum amount of liquid steel that the furnaces could supply. After the mould was completely cored up and top parts in position, the next step was to bind the whole job down. Several large bars known as porter bars, were placed along and across the mould and were securely anchored down into the sockets of the steel lining of the pit sides. The binding down is of the utmost importance to counteract the tremendous upward pressure which occurs during the casting operation. Since, due to their structure, the two overhead cranes carrying the end ladles, were unable to get close enough to the mould, launders or runner boxes 24-ft. long were used to carry the liquid steel from the ladle outlet stoppers to the mould. The centre ladle, which stood on a prepared platform, fed the centre down-runner into the bottom of the mould. Prior to actual casting a full timing of the cycle from the tapping of the furnaces to the transport of the metal to the mould, was prepared, and a full rehearsal was carried out to make sure all was in perfect order, ladles, lifting heights and the crane conditions were also checked.

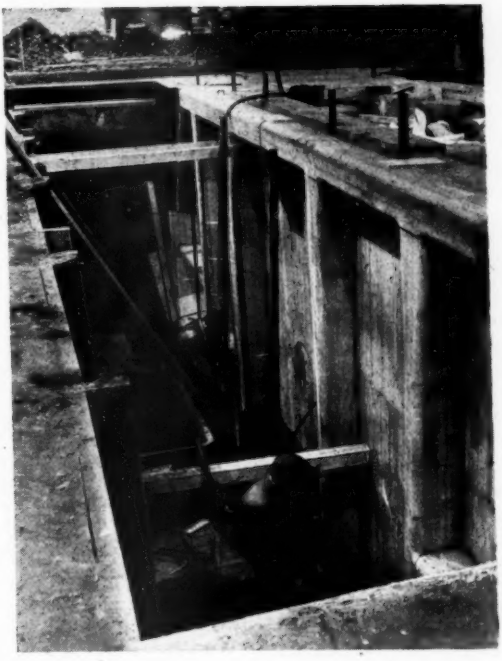


FIG. 5.—*Cross-head pattern lying in the casting pit at the commencement of ramming.*

FIG. 6.—*Mould faces being finished-off with chamotte paint.*

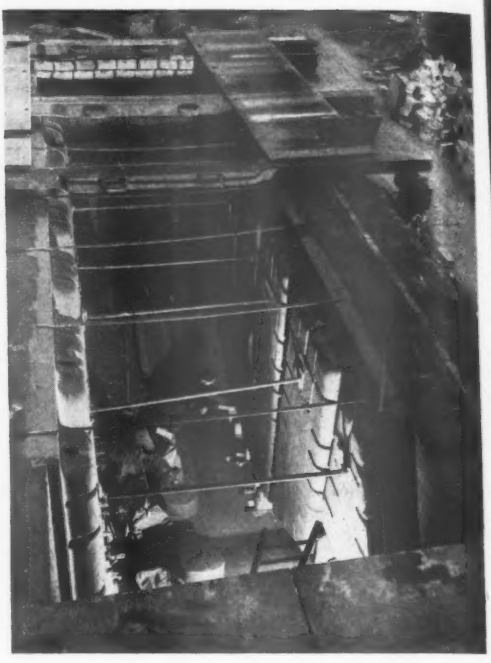


FIG. 7.—*Finished mould prior to drying, showing support bars and firebrick reinforcement.*

Pouring

The pouring was commenced from the centre ladle first, and a few minutes later, the two end ladles were opened up. Pouring continued at the rate of approximately 11 tons per minute, the whole casting operation taking 19 minutes, during which time 206 tons of liquid steel were transferred to the mould. After the ladles were emptied, the level of the liquid steel in the feeder heads was about 32 in. A very careful control was then maintained, and when the level had fallen 6 in. in an hour, 10 tons of electric-arc melted steel was run into the feeder heads, bringing the level up to 42 in. After this, a steady fall continued and within two hours a further drop of 8 in. was recorded. Another 5-ton charge of electric-melted steel was then added, and a steady fall in the heads was recorded in the next three hours, the level then being down to but 12 in. above the casting. A further eight tons of liquid steel was at this juncture fed into all the heads, bringing the level up to 38 in. and, after two hours, this level had again dropped 10 in. At this stage, in order to re-heat all the slag and steel in the heads, 1½ cwt. of a proprietary exothermic material was fed into each head, followed within an hour by a final eight tons of liquid electric-melted steel. The whole feeding operation took about seven hours, and it was then considered that further liquid feeding would not be effective. Fig. 10 shows the feeding chart.

Annealing and Dressing

Four days after pouring, when the top of the casting had solidified, the top boxes and binders were stripped off and the sand was cleared away from the feeder heads, which were then burned off to within 9 or 10 in. of the top of the casting proper by oxy-acetylene lance. After then allowing the casting to cool-off in the pit for three weeks, the mould sides and ends were roughly cleared of moulding sand and the casting eased for lifting. Owing to the tremendous suction, it was realized the casting could not be lifted immediately by overhead cranes, so two heavy-section steel girders were placed across the pit, and fastened to the lifting lugs already cast on the casting. Then by means of hydraulic jacks under each end of the girders the casting was slowly raised from its bed. Some idea of the heavy suction opposing the first movement can be gained, when it is realized that the load on the jacks registered 700 tons. At this stage, the casting was lifted a distance of about 12 in., and then allowed to cool off for a further few days, as the bottom of the casting was still red hot. It was then possible to commence rough cleaning of the casting whilst it was still in the pit, to remove as much as possible of the sand mass so that the cranes would not be overloaded. The casting was then hoisted clear of the pit and final rough cleaning of the internal cores took place. After all the

FIG. 8.—*First cores placed in position; a careful check was made on all thicknesses.*

cored and outside surfaces had been rough cleaned, the casting was transported, by special trailer, to a pit-type annealing furnace for heat-treatment. The annealing and cooling cycle, which had already been decided before manufacture commenced, took approximately three weeks, after which the casting was lifted into the dressing department for final cleaning and burning off, and the grinding of the remaining heads. Fig. 11 shows the casting after these operations were completed, it is suspended in a crane with a crane-type weighing machine checking its weight. When the finished casting received its dimensional check up, it was gratifying to find that the contraction allowances made on the pattern, had worked out to within a fair limit and all surfaces to be machined would clean up to the drawing dimensions.

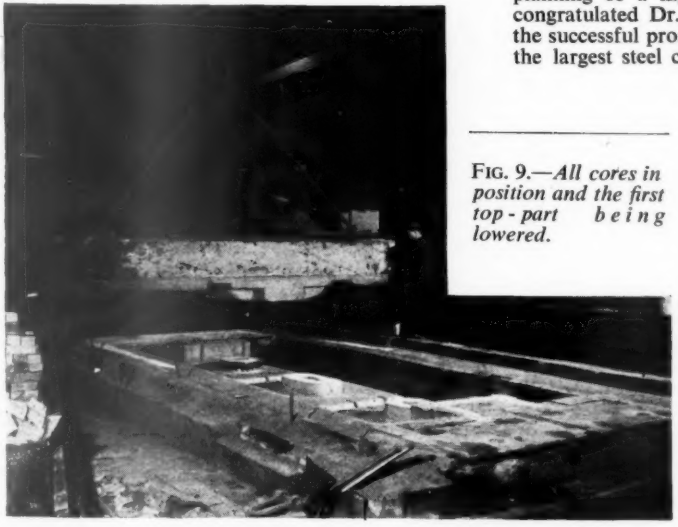


FIG. 9.—*All cores in position and the first top-part being lowered.*

Acknowledgment

The Author wishes to record his thanks to the directors of English Steel Corporation Limited for permission to publish this Paper and for the assistance given by colleagues.

DISCUSSION

Following the presentation of the Paper, the CHAIRMAN (Mr. John Bell) said he did not know what members' reactions would be, but to him it was an amazing feat. Mr. Taylor and those who worked with him on this job were men with big hearts, high courage and great resolve. Any suggestion as to how their work could be improved he would be glad to hear.

MR. E. LONGDEN opening the discussion said that the audience had indeed been favoured with a lecture and film outlining the production of such an unusually large steel casting, made by the English Steel Corporation, Sheffield. The emphasis on teamwork was fully justified in most things, especially when producing very large castings which required the combined skills of foundry and patternshop craftsmen, laboratory staff, heads of departments, along with engineering knowledge and executive planning of a high order. In this connection he congratulated Dr. Dadswell who had been behind the successful production of this large job, probably the largest steel casting made in Britain and made for export to the U.S.A. This casting order was taken in competition from abroad and great credit was due to the directive head who required much courage and resource to pledge his firm to make this casting.

MR. TAYLOR said he expected there must be behind many minds the question as to how long it took to produce the casting. The actual moulding and finishing time was approximately 900 hours; moulders' closing and binding time was approximately 400 hours, and coremaking ran to about 600 hours.

MR. LONGDEN asked had they encountered any of the usual steel founding troubles—draws, hot-tears, etc.?

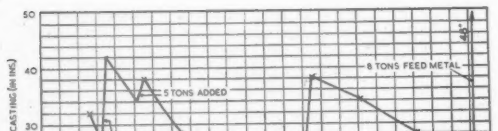


FIG. 10.—*Feeding chart for the cross-head beam casting, where feed-metal additions and feeder-head level are plotted against time.*

Dealing with this point MR. TAYLOR said they had done very well. He could not say that such a casting had been made without the slightest difficulty, and there were one or two small rectifications. However, in the first casting such matters were quite minor, and in the last casting insignificant. There was very little difficulty with tearing. The customer's original design was altered somewhat as the radii at all angles were at first extremely small for walls eight and ten inches thick. The body had been slightly thickened up into a good radii and a lot of tearing was prevented. Extra brackets were also added as shown.

Moulding Materials

MR. ROGERS said he felt very humble speaking about steel castings because he had had nothing to do with making those above seven tons each in weight, but he noted that Mr. Taylor and his colleagues had the same sort of troubles as he did, with refractories. He had had much experience of burning-in and he had been wondering if the moulders' "compo" used was completely successful. Had the zircon type of materials been tried? These he believed were very successfully and extensively used in the States. Such materials effectively resisted penetration, by all metals. With the jacket cores of large cast steel Diesel heads, before zircon-base sand was used, one casting took a trimmer 27 hours to remove the core wires alone, and the rock-like core material had still to be removed. The next casting was made in the zirconia mixture, and the core irons and cores were removed in an hour. Quite frankly, he thought it a revolution in foundry practice and he was wondering whether the English Steel Corporation had experimented with zirconia material. He had noticed the absence of any type of chills, but would have thought a number of chills might have been included to promote solidification.

MR. TAYLOR said he thought the "compo" materials used was the finest refractory for the heavy sections which went from eight inches in the thinnest part to 10 or 12 in. in the thicker sections. Zirconia was used extensively for thinner-section work, but not for such heavy sections. He had seen zirconia sand used in America but always for quite thin castings.

As to chills, none was used. The impression which had been given of chilling was in the top about the centre core. There was a tremendous strain on the centre core once one got the first flow of steel and chaplets were merely used there to check the strain.

Answering further questions put by another member, Mr. Taylor said that the total amount of the liquid steel used was about 237 tons for the casting, which had a total weight of about 185 tons. The feeder heads and waste material amounted to about 28 per cent. That was, he thought, a fine yield for a casting of that description. On larger jobs, such as large mill housings, where a heavy section was normal, as low as 25 per cent was required for heads and feeders, and gave satisfaction providing they were properly positioned.

Holding Down

MR. HAYNES was most interested in the bolting down of the cores and asked how the girders were fixed outside the pattern to withstand the strain of the bolts which held the centre down. A strange thing about bolts, was that sometimes the bolt head sometimes strained and up came the work. In the present case, the bolts must have taken a very heavy strain.

MR. TAYLOR said the provision for bolting the cores down was made in the mould before the bed was struck off. Rail sections were laid right across the bed in position where the cores were going to be. Two 1¼-in. dia. bolts were anchored to them. Members had not seen the bolts in the film, but if they remembered seeing the core and noticed the refractory sleeves in them, these marked the position. Rammed up in each core were three cast-iron grids and between each grid there were firebricks, so that it was a structure of iron to brick throughout the core. On the top grid, there was provision made for a fish-plate through which a bolt was threaded and fastened down, the core being then made up.

MR. HAYNES remarked that he supposed the calculating of the strength of the bricks and iron grids was all done before the cores were made up.

MR. TAYLOR said the calculation was left to the craftsmen in the shop. It was supervised, of course, but the personnel were so used to those heavy jobs that they could be relied upon. The foreman in the shop saw that he had ample strength in the core to withstand the strain. If Mr. Haynes was wondering how the rigidity of the pattern on the bed was maintained—it was done by girders laid in the bed. Another thing not shown on the film was that between the pattern and the inside of the steel-lined moulding pit several old ingot moulds were rammed in, well up to the pit side. They provided weight on the bottom anchors and served a second purpose because they could be easily removed before taking the first lift for stripping the casting. The rails went right through the bed into the outside of the mould.

Team-work

Dr. C. J. Dadswell acknowledged the very kind things which Mr. Longden had said about English Steel Corporation and the men who had produced such a fine casting. They were, he said, rather more used to problems arising in the manufacture of big castings than those who had had no experience of such work, and it was not therefore such a tremendous step to go from castings of 135 tons (before the war) to 185 tons. It had always been his ambition to make a casting of at least 150 tons. When he negotiated the present contract with the American customers on behalf of a group of manufacturers of whom he happened to be chairman, they encountered Italian, French and even German and Japanese competition. The design of the casting at the time of quoting was estimated at 165 tons, but it was later increased in strength and weight. On the actual job, matters went very much better than was expected and they did not have any of the troubles feared. That anticipation of possible difficulties, he thought, was probably why the work was so successful; for everyone it was a question of team-work. The whole project was carefully thought out from the start, with models and drawings and sections, and talks between technical personnel and the foremen who were going to make the job. Of course, it being such an interesting and unusual job, the men in the shop, moulders and core makers, actually did put into it their best craftsmanship.

With regard to burning-in—before heavy castings were annealed, there was always what appeared to be burning-in, but after annealing, the sand largely broke away, and the finished castings had very little sand on them. The most difficult part to clean was the inside of the cored holes because of the enormous pressure and temperature at pouring.

As to difficulties, one of the most serious troubles was segregation under the heads, leading to a danger of cracking when heads were removed.

On the question of yield, it had been mentioned that some of the castings made by the firm gave as high a yield as 75 per cent, but that was obtained with electric-arc heating of the feeder heads. He had been rather anxious to use arc heating on the particular job described, the reason being that not only did such practice increase the yield, but also it conferred a feeling of greater security. However, as could be seen from the diagram shown early in the Paper, there were ten feeders, and it was impossible for ten arc-heaters to be applied. Transformers had now been purchased which would enable the firm to apply eight arcs at once. He had been assured by his advisers that the 28-in. dia. heads shown were the optimum diameter to use to be really effective. It was thought that a large number at that diameter was better than fewer of 36-in. dia.

His company would be very pleased to lend the colour film during the course of the year, if any branch of the Institute wished to borrow it. The colouring was particularly appropriate in the view of tapping the three furnaces; that was one of the finest shots he had ever seen. The film had been produced for educational and publicity purposes and represented a chance which might never again come in a lifetime.

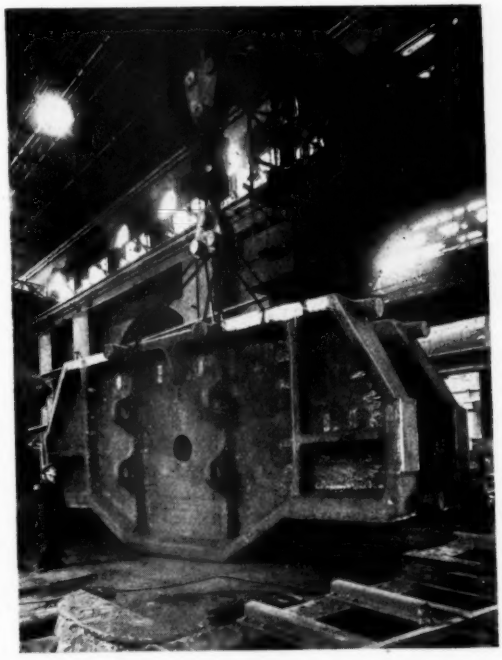


FIG. 11.—*Finished casting ready for transportation after quality checking and weighing.*

There was also available a complete series of lantern slides showing in more detail the whole manufacture.

THE PRESIDENT, closing the meeting, said he was glad that Paper had been included in the programme because it showed some of the things which he had tried to bring out in his presidential address—that there was a need for skilled craftsmen. To Mr. Taylor and Dr. Dadswell and his co-directors and the skilled workmen in the shop, members owed a great debt for the information given in the Paper and the way in which it was presented.

The President's remarks were supported with hearty applause. Mr. Taylor briefly replied in recognition and this concluded the meeting.

Institute of Metals Autumn Meeting

The 46th autumn meeting of the Institute of Metals will be held in Switzerland, September 6-14, by invitation of the *Société Suisse des Constructeurs de Machines* and the *Association Suisse pour l'Essai des Matériaux*. The meeting will open in Zürich on Monday, September 6, and members and ladies will leave Zürich on Saturday, September 11, for Montreux, until the afternoon of Tuesday, September 14, inclusive. A full programme of papers and works visits has been arranged.

F

Murdock Bicentenary

Commemoration, on August 21, of the bicentenary of William Murdock has revived interest in the history of the Soho Foundry and in the relics, housed in the Midlands and elsewhere, of the man. who chiefly known as the inventor of gas lighting, worked with Boulton and Watt at Smethwick on foundry developments that have now taken on epic and historic value.

It was in 1777 when Murdock, who was Ayrshire born, decided at 23 years old to seek work at the foundry where steam engines were being made. He chose to visit the Smethwick works, not necessarily because of what they had to offer but because his father had had an invention developed by a Birmingham man, Dr. Roebuck of the Carron Ironworks, who knew James Watt; young Murdock hoped to seek out his fellow countryman and hoped to be offered work.

On the now famous first call at the Soho Foundry, Murdock found to his disappointment that Watt was not available and he was interviewed by Boulton. Boulton had no great need for new entrants and Murdock, raw and unprepossessing, made no great impression. It was touch and go, therefore, until Boulton, commenting on Murdock's hat, learned that the Scot had turned it himself on a lathe of his own making. The inventor in Boulton thus responded to the inventor in Murdock, and the young man was engaged at a wage of 15s. a week. Watt sent him to Cornwall, where he remained for 19 years making steam engines and, in due course, married. While there, he produced the historic steam engine, the crude model of which is now in the Birmingham Art Gallery. This model, presented to Birmingham by Tangye's, is 19-in. long and 14-in. high; it has a copper boiler with firebox and flue. In the same museum are several drawings and manuscripts relating to Murdock's inventions.

Back at Smethwick

His colleagues, developing the Soho Foundry, were, however, quite indifferent to the Cornish experiments. "I wish William could be brought to mind the business in hand," Boulton wrote to Watt and the advice of the seniors seems for a time to have been effective because a little later Boulton was reporting that "Murdock has neither thought upon nor done anything about the steam engine, having so much to do about the mines." Back at the Smethwick Foundry, however, and living in his house at Handsworth, Birmingham, Murdock was soon back at inventing—this time with gas lighting. Wednesbury museum to-day treasures a piece of the gas piping which was taken up from the floor of his Handsworth home—one of the earliest pieces of such piping in existence. Murdock mattered now to the Soho Foundry, both to its principal partners and to its reputation. Boulton and Watt, not wanting to lose him, paid him a salary of £1,000 a year, a princely sum in those days. Before this, Murdock had experimented with setting up his own foundry in Scotland and the Smethwick pair "saw the red light" and raised the evaluation, a gesture which successfully retained Murdock for Birmingham.

The rest of the story is well enough known. In 1803—having the previous year publicly illuminated the Soho works with gas to celebrate the Peace of Amiens—Murdock erected plant for equipping the whole of the Soho Foundry with gas lighting. It was a personal triumph and Murdock was well satisfied. When he died, he was buried alongside the other two engineers with whom he had made the Smethwick premises famous.

Laymen think only of Murdock as the inventor of gas lighting, but he also invented stone-boring machinery

(*Continued at foot of Col.* 2.)

and found an economical substitute for isinglass, made from fish skins. Murdock also made a direct-acting blast engine. He is commemorated by a bust in the Hall of Heroes in the National Monument at Stirling.

Mr. William Bloye, the Birmingham sculptor, has completed his cast of the figure of William Murdock which is to form the Boulton, Watt & Murdock Memorial to be placed on a site at the Civic Centre, Birmingham. The model is now in the hands of the bronze casters, and it is expected that the group will be ready by next spring. The memorial was commissioned by the late Mr. Richard Wheatley. Mr. Bloye has been engaged on the task for three years and the figures of Watt and Boulton are already cast in bronze.

Mercast Process Agreement

Guest, Keen & Nettlefolds, Limited, and the Mercast Corporation of New York, announce that they have formed a company under the name of Mercast (Great Britain), Limited, to license firms in the U.K. and the British Commonwealth (excluding Canada) to use the Mercast process. This is a method of investment casting in which patterns of frozen mercury replace the more usual wax patterns, permitting very close tolerances, smooth finish and the ability to make more complicated and larger castings than are sometimes practicable with the lost-wax method.

In the United States, the Mercast process is finding wide application in the aero-engine field, being used for substantial production of components for the Wright turbocyclone, hollow turbine blades, for radar waveguides, guided-missile components and in atomic energy plants. The chairman of the new company is Mr. G. R. Sankey, C.B.E., of Joseph Sankey & Sons, Limited, Bilston, Staffs. The other directors are:—Dr. T. Emmerson (G.K.N. Group Research Laboratories); Mr. K. O. G. Huntley (Lovell, White & King, solicitors, London); Admiral A. G. Kirk, U.S.N. (retd.) (Mercast Corporation, U.S.A.); Mr. W. A. Nicol (G.K.N.) and Mr. S. J. Sindeband (Mercast). The registered office of the new company is at Albert Street, Bilston, Staffs. The technical manager is Mr. C. Dykes, M.A.M.S., who will, however, continue to operate as an advising aeronautical engineer, in which capacity he is retained by aircraft, engine and accessory firms in this country, the United States and Canada.

Cast Iron in Architecture

Though Gardner's furniture warehouse in Jamaica Street, Glasgow, may be the only considerable building left in the city with its facade wholly in cast iron, it was by no means unique in its day. Glasgow is, in fact, quite rich in remains of the "cast iron age," which flourished from about the fifties to the eighties of last century. Among others, the Buck's Head Buildings in Argyle Street boast some very delicate pillars and arches. The metal has the advantage that it is strong, durable (Gardner's 98-year-old building looks as good as new) and can be easily cast in repetitive forms. It was this repetition that was probably its undoing as designs came to be very stereotyped and building pieces were often sold right "off the peg." Architects are now going back to cast metal, however, as can be seen in the very handsome mullions and window apron panels on the Scottish Legal Building in Glasgow. One difficulty to-day, however, is the scarcity of patternmakers and moulders who can turn out such delicate tracery.

Centrifugal Method of Metallurgical Research*

By R. V. Riley, Ph.D., B.Sc., F.I.M. and B. T. Gillyatt

(*Continued from page* 217)

X—Effect of Sedimentation and Convection Currents in Molten Metal Cooled from the Outside

In all the experiments which were carried out, the molten metal was cooled either by reducing or switching off the furnace current. The metal was therefore cooled from the outside and the outer part of the melt would freeze first. Any inclusions attempting to segregate near the walls of the crucible or being carried along by the convection currents would then probably be caught in the dendritic structure as shown in Fig. 8.

This view is based on the micrographic examination of bearing metals which have been melted and solidified under strong gravitational fields. As referred to earlier in this Paper, whilst there was almost complete segregation of the antimony/tin cuboids to the top of the metal, in most cases some of the cuboids also appeared to have been trapped in the dendritic structure forming at the cylindrical surface of the ingot.

XI—Experiments with Phosphoric Foundry Irons

This investigation was entirely with typical phosphoric irons of foundry compositions. An attempt was made to investigate variations in manganese and sulphur contents. The samples of iron upon which experiments were made, were analysed and the compositions are recorded in Table VI. The general experimental method was to melt the specimens of iron and then to allow them to solidify whilst maintaining the iron under a given gravitational force. Specimens of the compositions recorded in Table VI were subjected to melting and solidification cycles both spun and static. The rates of cooling were operated between 10 deg. and 60 deg. C. per minute over the range 1,300 deg. C. to 750 deg. C.

In the following text, the effect of spinning on cast iron was investigated from the points of view of changes in macro- and micro-structures, changes in composition especially in sulphur and phosphorus, and including gas content variations. Measurements were also made of thermal arrest points, phase changes, etc.

TABLE VI.—*Percentage Compositions of Cast Irons Used in Experiments.*

Experimental Cast No.	T.C.	Si	Mn.	S.	P.
250	3.38	2.27	0.31	0.085	1.09
258	3.30	2.35	0.25	0.094	1.25
270	3.38	2.37	1.63	0.067	1.20
272	3.32	2.30	0.63	0.199	1.24
72	3.36	2.25	0.25	0.09	1.00
73	3.36	2.25	1.30	0.09	1.00
74	3.36	2.25	0.58	0.24	1.00

*Paper presented at the fifty-first annual meeting of the Institute of British Foundrymen, held in Glasgow.

XII—Influence on Spinning on Thermal Arrests with Cast Iron

Temperature measurements were made primarily to ensure a knowledge of the rate of cooling in order that the rates of cooling of spun and static melts could be matched so as to obtain comparative information. As the primary aim of the experiments was a micrographical examination, it was necessary to keep the specimen intact and free from non-metallics such as a thermocouple sheath, so that the small ingot could be sectioned longitudinally for micro examination. It was also considered important to have no unnecessary contacts with solid matter in the melt. The molten iron was, therefore, in contact only with the crucible which, of course, was indispensable. For these reasons, the thermocouple was inserted, as has already been described, in the annular space between the crucible and the furnace tube.

The lack of direct contact of the thermocouple with the molten metal made the detection of critical phase changes more difficult and less definite than if the thermocouple sheath had been in the melt. Despite this, the e.m.f. measurements made with the potentiometer were sufficiently precise to enable a cooling curve to be plotted which gave the three major change points reasonably clearly. These were

FIG. 9.—*Typical cooling curves of static and spun melts. Iron composition (per cent.) T.C.* 3.38, *Si* 2.37, *Mn* 1.63, *S* 0.067 *and P* 1.20; *slowly cooled.*

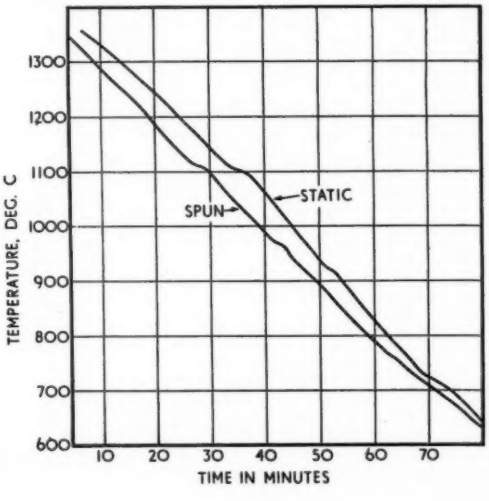


TABLE VII.—*Thermal Arrest Points in Spun and Static Cast Iron.*

Condition of Experiment.	Percentage composition.					Arrest temperature (deg. C.)		
	T.C.	Si	Mn	S	P	Liquidus.	Phosphide Eutectic.	Eutectoid.
Slowly-cooled:								
Static melt, 1 g.	3.32	2.30	0.63	0.199	1.24	1,112	930	752
Spun melt, 1,000 g.	3.32	2.30	0.63	0.199	1.24	1,146	940	780
Slowly-cooled:								
Static melt, 1 g.	3.30	2.35	0.25	0.094	1.25	1,105	932	750
Spun melt, 1,000 g.	3.30	2.35	0.25	0.094	1.25	1,120	965	715
Slowly-cooled:								
Static melt, 1 g.	3.38	2.37	1.63	0.067	1.20	1,107	924	727
Spun melt, 1,000 g.	3.38	2.37	1.63	0.067	1.20	1,110	968	765
Quickly-cooled:								
Static melt, 1 g.	3.32	2.30	0.63	0.199	1.24	1,110	915	720
Spun melt, 1,000 g.	3.32	2.30	0.63	0.199	1.24	1,110	910	740
Quickly-cooled:								
Static melt, 1 g.	3.30	2.35	0.25	0.094	1.25	1,115	N.D.	680
Spun melt, 1,000 g.	3.30	2.35	0.25	0.094	1.25	1,107	945	690
Quickly-cooled:								
Static melt, 1 g.	3.38	2.37	1.63	0.067	1.20	1,098	900	700
Spun melt, 1,000 g.	3.38	2.37	1.63	0.067	1.20	1,090	920	720
Quickly-cooled:								
Static melt, 1 g.	3.36	2.25	1.30	0.090	1.00	1,060	N.D.	700
Spun melt, 1,000 g.	3.36	2.25	1.30	0.090	1.00	1,050	N.D.	750

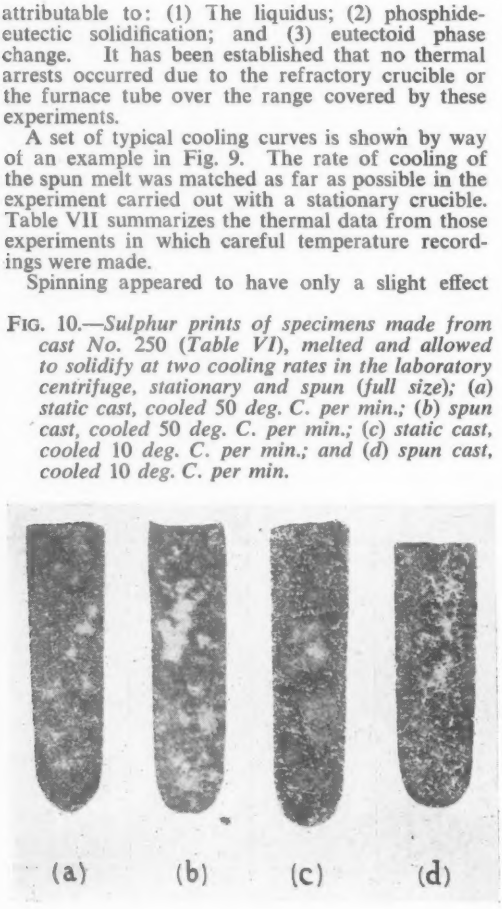
N.D. = not detected.

attributable to: (1) The liquidus; (2) phosphide-eutectic solidification; and (3) eutectoid phase change. It has been established that no thermal arrests occurred due to the refractory crucible or the furnace tube over the range covered by these experiments.

A set of typical cooling curves is shown by way of an example in Fig. 9. The rate of cooling of the spun melt was matched as far as possible in the experiment carried out with a stationary crucible. Table VII summarizes the thermal data from those experiments in which careful temperature recordings were made.

Spinning appeared to have only a slight effect upon the thermal arrests for each of the iron compositions recorded in Table VI. The main influence was on the phosphide eutectic arrest which occurred at a slightly higher temperature in spun melts. The other variations were very slight and somewhat contradictory. They did not appear to be capable of close analysis at this stage. The effect of more rapid cooling was to lower all the thermal arrest points, whether in static or in spun experiments. This effect is in line with what would be expected.

FIG. 10.—*Sulphur prints of specimens made from cast No.* 250 (*Table VI*), *melted and allowed to solidify at two cooling rates in the laboratory centrifuge, stationary and spun (full size); (a) static cast, cooled* 50 *deg. C. per min.; (b) spun cast, cooled* 50 *deg. C. per min.; (c) static cast, cooled* 10 *deg. C. per min.; and (d) spun cast, cooled* 10 *deg. C. per min.*



XIII—Sulphur Segregation

It is generally believed that the manganese-sulphide particles are buoyant in liquid iron and this would be expected from a consideration of their specific gravities (see Table V). The flotation of manganese sulphide is frequently observed in the foundry and occurs even under the normal influence of gravity, as for example, in a ladle or in a large vertical casting during solidification. Most spun cylindrical castings also show a higher concentration of sulphur upon the inside surface. The specimens of iron spun in the laboratory centrifuge showed a loss of sulphur during spinning which was due to the flotation of some of the sulphide to the surface

TABLE VIII.—*Effect of Centrifuging Experiments upon Sulphur Distribution.*

Cast No.	Original, Mn, per cent.	Iron spec. S, per cent.	Details of run.	Final sulphur, per cent.
258	0.25	0.094	Static, slowly cooled ..	0.084
	0.25	0.094	Spun, slowly cooled ..	0.085
258	0.25	0.094	Static, quickly cooled ..	0.094
	0.25	0.094	Spun, quickly cooled ..	0.087
270	1.63	0.067	Static, slowly cooled ..	0.045
	1.63	0.067	Spun, slowly cooled ..	0.026
270	1.63	0.067	Static, quickly cooled ..	0.065
	1.63	0.067	Spun, quickly cooled ..	0.054
272	0.63	0.199	Static, slowly cooled ..	0.130
	0.63	0.199	Spun, slowly cooled ..	0.117
272	0.63	0.199	Static, quickly cooled ..	0.187
	0.63	0.199	Spun, quickly cooled ..	0.161

of the molten metal where it became incorporated in the slag layer. The degree of removal of sulphur was, however, not complete, as shown in Table VIII.

A careful consideration of Table VIII indicates that the simple empirical rule relating to the removal of sulphur as manganese sulphide, which is thereby removed from the sphere of influence of the molten iron, is only partially true. Cast No. 258 was of an iron low in manganese and out of balance with the sulphur content according to the generally-accepted rule, *i.e.*,

Total percentage manganese = 1.7 × per cent. sulphur + 0.3.

It is interesting to note that some reduction in sulphur occurred on centrifuging, despite there being insufficient manganese to account for the formation of manganese sulphide. Possibly this is due to the flotation of iron sulphide (specific gravity = 5.02).

By calculation from the above formula, the manganese necessary to balance the sulphur present in cast No. 270 is:

Per cent. manganese = 1.7 × 0.067 + 0.3
= 0.41 per cent.

From the formula, all the sulphur in this iron should be in the form of manganese sulphide, since there was a large excess of free manganese. Although much of the sulphur was removed by centrifuging, Table VIII shows that some remained and sulphur prints confirmed this result.

With cast No. 272, exactly the right amount of sulphur was present to balance the manganese, yet this specimen retained 65 per cent. of the original sulphur even after centrifuging at 1,000 g. and slowly cooling from the molten state.

i.e., Percentage manganese required in formula = 1.7 × 0.199 + 0.3
= 0.64

Percentage manganese by analysis = 0.63.

A significant amount of sulphur still remained in the specimens whether statically cobled or centrifuged in all the experimental melts, presumably in the form of sulphur in solution with the ferrite, or perhaps as particles of FeS and MnS too small to be affected by the flotation tendency in the time of the experiment. The rapid convection currents in the molten iron in a gravitational field at 1,000 g. would also help to keep small particles in suspension, so that they remained unaffected by Stokes law during the time of the experiment. Whichever be the correct explanation, and the Authors can find evidence in favour of both, it is certainly true that sulphur is fairly uniformly distributed through the cross section of the specimens, as clearly indicated by the sulphur prints shown in Fig. 10. The presence of manganese-sulphide particles was also confirmed by metallographic examination.

XIV—Gas Content of Centrifuged Iron

Some of the samples were analysed for gas content in the vacuum fusion apparatus in order to determine the effect of centrifuging. It was necessary to take the whole of the sample for gas analysis: for this reason, duplicate experiments were carried out and the ingot produced was cleaned by grinding off the outer surface and by removing the top ¼ in. to avoid slag inclusions. Similar analyses were made of specimens melted and cooled in the experimental crucible without being spun. The two sets of results given in Table IX are the average of duplicate runs in each case.

TABLE IX.—*Gas Content of Spun and Statically-cast Iron.*

Cast No.	Conditions of experiment.	Gas content in parts per million. Hydrogen.	Oxygen.	Nitrogen.
73	Sample melted and cooled in static crucible	3.5	44	42
73	Sample melted and cooled in spun crucible at 1,000 g. ..	1.9	24	40
74	Sample melted and cooled in static crucible	2.6	72	49
74	Sample melted and cooled in spun crucible at 1,000 g. ..	2.1	28	54
—	Average of 30 samples for gas analysis from melt of phosphoric cast iron* prior to spinning pipe. Sample annealed	1.7	12	20
—	Average of 30 samples for gas analysis from phosphoric cast iron* pipe spun at 60 g. during manufacture. Sample annealed	1.7	10	22

* Typical composition (per cent)	T.C.	Si.	Mn.	S.	P.
	3.4	2.5	0.25	0.08	1.10

The iron melted in the stationary crucible appeared to take up oxygen which was partly eliminated by spinning at 1,000 g. There appeared to be a slight reduction in hydrogen content due to centrifuging and a small pick up in nitrogen. These results were not of great significance since they represent in total only eight separate experiments made on two iron compositions. More extensive work in the laboratory on spun-pipe castings showed very little change in the gas contents due to spinning. The average of thirty estimations given in Table IX shows that when the gas content of the iron was originally at a low level spinning at 60 g. on the pipe plant had little effect. It is possible, of course, that the effects found in the laboratory centrifuging experiments at 1,000 g. were typical of the behaviour of iron with a higher general gas content.

If the experimental results quoted here are acceptable, it must be concluded that even at a gravitational field increased to 1,000 g., the hydrogen and oxygen are not completely removed and the nitrogen figure is, in fact, slightly raised. The flotation of slag-like and non-metallic matter would account for the lower oxygen contents in the spun ingots. The method of sampling, however, may not have removed entirely the floated material. The fact remains that the iron from the laboratory apparatus, whether static or spun cast, was

FIG. 11.—*Longitudinal cross-section of specimens, showing points at which a spectrographic analysis was made.*

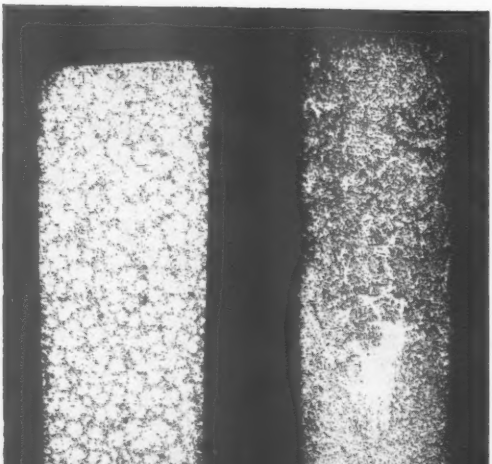


FIG. 12.—*Photomacrographs of the same iron (cast No. 272, Table VI) cast (a) (left) statically, and (b) centrifugally at 1,000 g. × 2.*

higher in hydrogen, oxygen and nitrogen than the iron from a spun pipe of similar general composition. This may be partly due to the previous history of the iron which was made synthetically in an induction furnace.

XV—Effect of Spinning on Trace Elements Distribution

Some of the iron specimens were examined for trace elements. Spectrographic examination was carried out at selected points across the section of the ingot cut longitudinally. (See diagram, Fig. 11.) Only those specimens were taken which had been fairly quickly cooled so that a fine grain structure resulted which was suitable for spectographic analysis. The silicon and manganese values tended to be low against the figures obtained by chemical analysis. This is due to the influence of a non-standard sample from the spectrographic point of view and is without significance.

The spread of results for silicon content was considered to be without significance and apparently a high centrifugal force was without influence upon the normal segregation of this element. The results for manganese confirmed the tendency for manganese or iron sulphides to flotation especially in the case of the high manganese iron, but there was little discernible effect with low-manganese irons. The only other observed effect was the trend towards higher titanium content near the top of the specimen in all melts, whether static or spun. Typical results of spectrographic examination are given in Table X.

XVI—Influence of Spinning on the Structure of Cast Iron

All specimens of cast iron melted and cooled in the laboratory crucible were sectioned longitudin-

TABLE X.—*Spectrographic Examination for Trace Elements.*

Cast No.	Details of run.	Sampling point.	Element (per cent.).						
			Si.	Mn.	Ni.	Cr.	V.	Ti.	Cu.
72	Static, quickly cooled	1	1.97	0.29	0.17	0.18	0.15	0.02	0.18
		2	2.03	0.31	0.17	0.17	0.17	0.03	0.17
		3	2.03	0.28	0.17	0.17	0.14	0.03	0.17
		4	2.03	0.29	0.17	0.16	0.16	0.04	0.17
		5	1.97	0.32	0.17	0.18	0.19	0.05	0.16
72	Spun, quickly cooled	1	1.93	0.36	0.17	0.19	0.13	0.01	0.18
		2	1.94	0.32	0.16	0.18	0.14	0.01	0.19
		3	1.94	0.37	0.15	0.19	0.16	0.02	0.19
		4	2.03	0.38	0.15	0.18	0.11	0.01	0.18
		5	1.95	0.35	0.16	0.16	0.12	0.02	0.20
73	Static, quickly cooled	1	2.20	0.99	0.14	0.18	0.14	0.02	0.16
		2	1.98	1.12	0.14	0.19	0.16	0.03	0.15
		3	1.95	1.16	0.16	0.18	0.14	0.03	0.16
		4	2.03	1.15	0.15	0.16	0.14	0.04	0.16
		5	2.13	1.21	0.14	0.15	0.14	0.04	0.17
73	Spun, quickly cooled	1	2.01	1.01	0.16	0.15	0.14	0.01	0.16
		2	1.97	1.07	0.17	0.14	0.14	0.01	0.17
		3	1.95	1.12	0.15	0.20	0.15	0.02	0.17
		4	2.17	1.06	0.14	0.14	0.17	0.02	0.16
		5	2.07	1.21	0.16	0.15	0.14	0.04	0.15
74	Static, quickly cooled	1	2.05	0.40	0.14	0.21	0.14	0.01	0.17
		2	2.17	0.50	0.15	0.18	0.16	0.02	0.17
		3	1.83	0.57	0.14	0.19	0.16	0.02	0.17
		4	2.07	0.53	0.16	0.24	0.13	0.04	0.16
		5	2.13	2.40*	0.15	0.16	0.11	0.04	0.18

* Effect of a slag inclusion near surface. See Fig. 11.

ally and one half was polished and etched for metallographic examination. During cutting, the spun-iron specimens were all found to be much harder than the specimens of irons of similar composition which had solidified in a stationary crucible. The hardness was due to the presence of internal chill. Macro-etching usually revealed a patch of white iron along the central axis of the specimen, as shown in Fig. 12*b*. The grain size of the spun specimens was smaller and there was an absence of the phosphide network structure generally present in iron of high phosphorus composition, see Fig. 12*a*. The exact position and amount of the hard zone varied, but it was generally located near to the central axis of the specimen and had a tendency to be in the lower half of the specimen.

Magnification at ×50 dia. showed that the area of internal chill was due to the presence of a phosphide/carbide complex and was typical of the phenomenon known in the iron industry as "inverse chill." Fig. 13 shows clearly the "inverse chill" in an iron of composition No. 258, Table VI, after being spun at 1,000 g. The area of "inverse chill" was sometimes patchy as in Fig. 12*b* and occasionally it occurred as a well-defined band running longitudinally near to the centre of the specimen, as in Fig. 13. Fig. 14 shows at a high magnification, the structural constituents of the "inverse chill" which was exactly similar to the same phenomenon seen occasionally in commercial irons. It was established beyond all question of doubt that the zones of "inverse chill" in spun specimens were not due to differences in the rates of cooling between static and spun ingots; in fact, the patches of "inverse chill" were more extensive in the slowly cooled spun specimens. Cooling at rates approximately equal to those used in the spun experiments, resulted in a completely grey iron in all cases with static melts (Fig. 15). No traces of "inverse chill" was found in any of the specimens produced by melting and solidifying in stationary crucibles. The centrifuge, therefore, offered a means of producing the phenomenon of "inverse chill" at will.

Spun specimens appeared to have a tendency to show the "supercooled" type of graphite (Fig. 16) rather than the coarse, flake-type graphite. This effect was not completely regular, however, and in Fig. 17 coarse flake graphite is shown adjoining an area of "inverse chill."

The specimens were all examined carefully for the presence of manganese sulphide and other inclusions. Irons with high sulphur and/or manganese all showed a concentration of manganese sulphide inclusions along the open top surface of the specimens. Fig. 18 shows a number of "anchor" and "dendritic" type manganese sulphide inclusions near to the top of the spun specimen (cast 74, Table VI). Other irons, low in sulphur and/or manganese, gave a less definite segregation of manganese sulphide (see section XIII). Traces of manganese sulphide inclusions, both the "anchor" type and the "compact" type, could be seen throughout most specimens whether cast statically or spun.

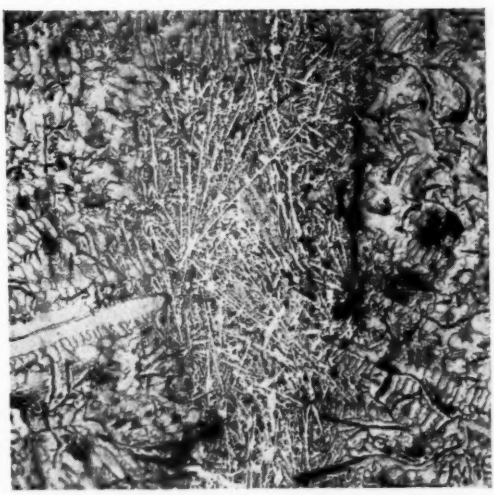
The phosphides in spun specimens tended to be in the form of agglomerates (Fig. 19). The uniform distribution of phosphides along a network pattern as found in ingots cast in a stationary crucible, gave place to a more irregular distribution. Some segregation of the phosphides appeared to have taken place, but this was not uniform in character. The separation of the phosphide phase, if it had taken place at all due to the increased gravitational field, was complicated by the other factors, namely, thermal currents, solidifying dendrites and perhaps also to the influence of vibration. The segregation of the phosphides is seen clearly in the lighter areas of the sulphur prints, Fig. 10.

Spun specimens, whilst showing ferrite in the regions of supercooling, tended to show more pearlite than was found in irons of equivalent composition cooled under stationary conditions (Fig. 15). This effect was rather variable and was not completely confirmed in all specimens.

XVII—Consideration of Results

The work described in this Paper was undertaken on the assumption that the centrifugal apparatus would be relatively simple to build and easy to work. Such was not the case; experimental difficulties cropped up which slowed down the work to such an extent that the original programme could not be accomplished in a reasonable time. Thus, the Authors are aware of the incomplete nature of the investigation as recorded. Only a very limited range of phosphoric grey cast irons have come under test. However, the results, incomplete as they are, appeared to be worth reporting since

FIG. 13.—*Patch of inverse chill in iron, cast No. 258, Table VI;* ×50.

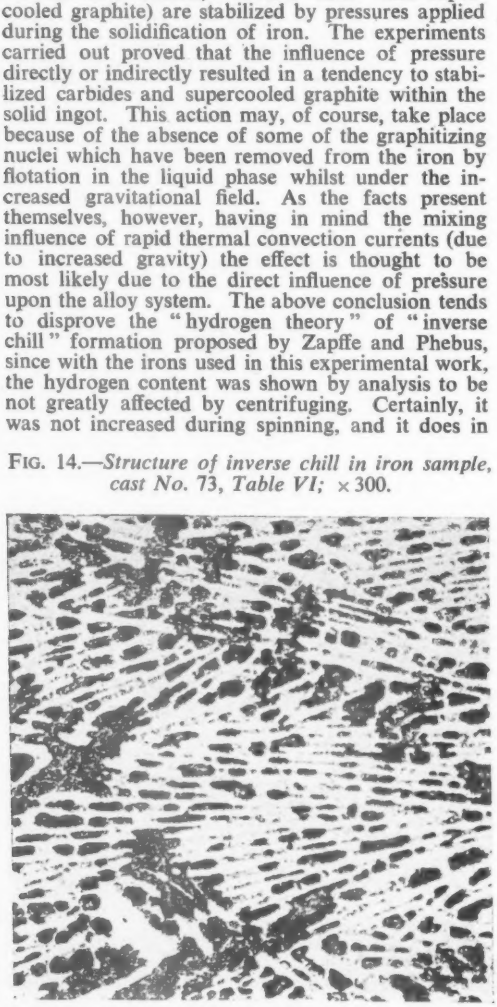


they throw light upon fundamentals of direct interest in the metallurgy of cast iron.

The phenomenon of "inverse chill" has been written about widely, and is thought to hold the key to knowledge of far reaching importance regarding the solidification of cast iron. It has been suggested by H. Morrogh[8] and others[9] that "inverse chill" is associated with the solidification of cast iron under some constraint which stabilizes and increases the persistence of the acicular carbides that go to make up "inverse chill" and "supercooled" graphite.

The experimental work of the present Authors tends to lend support to this idea that carbides (and, for the same reason, "inverse chill" and supercooled graphite) are stabilized by pressures applied during the solidification of iron. The experiments carried out proved that the influence of pressure directly or indirectly resulted in a tendency to stabilized carbides and supercooled graphite within the solid ingot. This action may, of course, take place because of the absence of some of the graphitizing nuclei which have been removed from the iron by flotation in the liquid phase whilst under the increased gravitational field. As the facts present themselves, however, having in mind the mixing influence of rapid thermal convection currents (due to increased gravity) the effect is thought to be most likely due to the direct influence of pressure upon the alloy system. The above conclusion tends to disprove the "hydrogen theory" of "inverse chill" formation proposed by Zapffe and Phebus, since with the irons used in this experimental work, the hydrogen content was shown by analysis to be not greatly affected by centrifuging. Certainly, it was not increased during spinning, and it does in fact appear to have been reduced somewhat. (See Table IX.)

FIG. 14.—*Structure of inverse chill in iron sample, cast No. 73, Table VI;* ×300.



The centrifuging failed to bring about the complete separation of manganese or iron sulphides, despite the appreciable degree of removal experienced under ordinary gravitational fields. It is interesting to reflect upon the possible reasons for this. The solid particles of manganese sulphide might have been too small to rise to the top of the melt in the time available (Stokes' law) and if so, would become caught in the solidifying matrix. There was a fairly uniform distribution of sulphur, as revealed by the sulphur prints, and particles of manganese sulphide were also detected throughout the specimens by metallographic methods. This explanation appears, however, too simple since at no level in the specimen, except the top surface, does a high concentration of sulphur appear. If the sulphur present in the spun iron is assumed to be present completely as sulphides, then its regular distribution in spite of the high centrifugal force, suggests that convection currents play a very important part. In section IX the convection currents have been shown to increase progressively with the increased gravitational field and the schematic drawing shown in Fig. 8 might then be adopted as a basis of the explanation. In this diagram it is postulated that the higher thermal convection currents due to the increased gravitational field sweep the solid sulphide particles around the melt in a cloud, to be deposited like sand in a dust storm in the crevices of the growing dendrites.

Alternatively, a large proportion of the sulphur in the iron may remain in solid solution in the austenite. Possibly, the general equation given below, is capable of subdivision into other reactions one of which may be pushed to the left by the effect of increased pressure on the alloy system.

Mn	+	S	→	MnS
(dissolved in liquid iron)		(dissolved in liquid iron)		(solid floating in liquid iron)

The experimental fact was that sulphur was not removed completely and the extent to which removal was effected depended not so much upon the centrifugal conditions as upon the percentage of manganese and/or sulphur present initially.

Phosphorus in spun specimens tended to appear in the form of agglomerates of phosphides forming in patches much larger than those in the normal phosphide network in an ordinary statically cast ingot. This agglomeration of the phosphides could have been brought about by the action of the growing dendrites of solidifying austenite squeezing out the lower freezing point phosphorus-rich material under the increased pressures which resulted from the higher centrifugal forces. No "bleeding" of the phosphide-rich particles was experienced in these experiments, probably because the surface of the molten metal froze before the end of the period of solidification.

No visual evidence of titanium carbide inclusions was found but the spectrographic results tend to suggest that perhaps the particle removal of titanium in some form, has occurred during spinning. This

effect might be important since the inoculating action of titanium carbide is well recognized. The opportunity to examine further this aspect did not occur.

Silicon, which is an element mainly soluble in the austenite or ferrite phases, was uniform throughout the entire cross-section of the ingot whether made statically or spun. The same is true of nickel, copper and chromium in the amounts present in the casts used in these experiments.

Acknowledgment

The Authors are pleased to record their great indebtedness to the directors of the Staveley Iron & Chemical Company, Limited, for permission to publish these results of a research carried out in the research laboratories of this company.

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[1] Prof. Benedicks and the Ingots Committee of the Iron and Steel Institute. "Heterogeniety of Steel Ingots," 1st Report. *Journal* Iron & Steel Institute, 1926, No. 1, 39-151.

[2] H. Morrogh. Written discussion to paper by C. A. Zapffe and R. L. Phebus. "Causes and Cure of Inverse Chill and Hard Spots in Cast Iron," *Trans.* Amer. Soc. Metals, **41**, 259-92.

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APPENDIX

When the above was delivered in Glasgow, MR. GILLYATT introduced ahe Paper and described the experimental work.

Next, DR. RILEY expanded the information given. He said that he would like to indicate the nature of further work which had been carried out since the Paper had been submitted for publication. All the irons referred to in the Paper had a phosphorus content of the order of 1 per cent. However, since publication, further experiments had been made in order to investigate the behaviour of low-phosphorus irons. Fig. A shows in section (*a*) an iron of phosphorus content 0.1 per cent., after slow cooling in a stationary crucible, in the centrifugal machine. Section (*b*) shows the same iron, cooled at the same rate in a spinning crucible in the machine. This latter specimen clearly shows inverse chill, and there were present also areas of under-cooled graphite.

The centrifuge thus offers a means of producing inverse chill at will and the Authors have considered the reasons for this interesting observation. The formation of inverse chill appeared to be due possibly to one or more of the following conditions:

(*a*) That under a high gravitational field, graphitizing "nuclei" were removed from the melt which then had a tendency for under-cooling and giving typical fine-graphite and inverse-chill areas.

(*b*) That the high gravitational field made phosphorus segregate to the central areas, where its presence caused phosphides and carbides having an acicular form, as recently demonstrated by Morrogh and Tutsch.

(*c*) That, in some way, the equilibrium conditions were altered by the higher pressure upon the solidifying melt, thereby resulting in the stabilization of carbides rather than graphite.

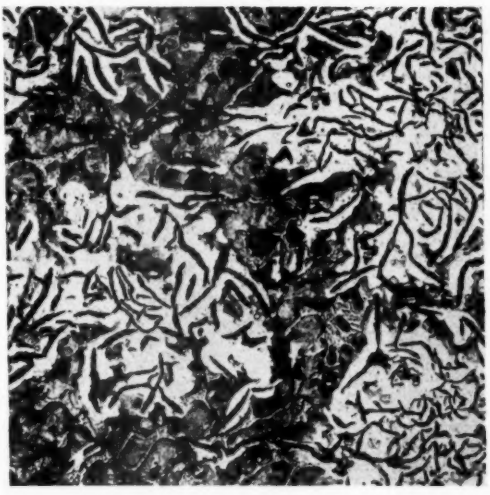


FIG. 15.—*Normal structure of phosphoric foundry iron; cast No.* 250, *Table VI; statically cast;* ×75.

Check Experiments

In order to check the first idea, the following experiments were carried out: A specimen of iron of 1 per cent. phosphorus, similar in composition to those upon which the bulk of the work was being carried out, was first allowed to solidify under centrifugal force of 1,000 g. The expected inverse-chill area was found (as in Fig. A (*c*)). The top ¼-inch of this specimen, which might be expected to contain the majority of the non-metallic inclusions (nuclei) was removed and the rest of the ingot was re-melted under identical conditions in the apparatus, except that it was not spun. The iron then had a normal structure on solidification, as in (*d*). If it were assumed that all the nuclei had in fact been removed, this demonstration might be construed to dispose of the nuclei theory. However, the findings recorded in the Paper on the presence of convection currents would not permit of such a sweeping conclusion.

An attempt was made to analyse chemically the small inverse-chill areas for phosphorus content, in order to check upon the tenability of the phosphorus-migration theory. Considerable experimental difficulty was encountered here because of the small size of the specimen. The figures obtained on a specimen containing about 1 per cent. of phosphorus were as follow:—

Inverse-chilled zone	..	1.19 per cent.
Soft, external zone	..	1.01 per cent.

With an iron of lower phosphorus, corresponding figures were:—

Inverse-chilled zone	..	0.17 per cent.
Soft, external zone	..	0.12 per cent.

Thus, there appeared to be some concentration of phosphorus in this central zone showing inverse chill, but hardly sufficient in itself to account for the

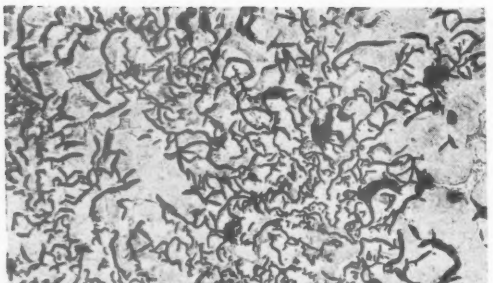


FIG. 16.—*Supercooled graphite in spun-iron specimen, cast No. 73, Table VI;* ×300.

observed differences in microstructure. In the absence of further experimental evidence to the contrary, the Authors were, therefore, forced to the conclusion expressed in the Paper that this phenomenon was probably due mainly to the direct effect of ferro-static pressure upon the iron/carbon/silicon system.

DISCUSSION

THE CHAIRMAN (Dr. A. B. Everest) said his impression on glancing through the Paper was that the results reported seemed rather disappointing, considering all the work that had been put into devising the research method described. He believed Dr. Riley agreed with that; he had already continued his studies and was obtaining some more interesting results, and one had a feeling that the Authors would get a great deal more out of the method as time went on.

It seemed to him that the lack of segregation, or the relatively small amount of segregation, the Authors were able to produce under the conditions quoted was the result of the convection currents, and he felt fairly sure that if they could modify or eliminate those convection currents by some means they would get very much more positive results.

Mr. GILLYATT said there was no doubt that the convection currents did play a large part in masking the segregation. On reference to section II(*c*) of the Paper, relating to uniformity of heating, one would see that over a considerable region of the crucible there was relatively uniform heating. It was extremely difficult to maintain a uniform temperature when there was such a large temperature difference between the specimen and the surrounding air. The curve in Fig. 5 indicated fairly uniform heating at a temperature of 1,340 deg. C., and if the Authors were able to keep the specimen at that temperature and then reduce it to room temperature instantaneously, presumably they would get the effect they wanted. As it cooled, however, there was no reason to suppose that the heat losses from the various parts of the crucible remained at the same rate. He and his colleagues would have to try to devise a means of getting more uniform heating over the whole temperature range, but it was not clear at present how this was to be achieved.

MR. H. MORROGH, after congratulating the Authors on the experimental technique they had developed, said he had noted from the Paper that they had expected that the work would be easy; but he imagined that most people would have been deterred from starting it by the thought of the difficulties they were likely to meet. However, they had demonstrated that their method was a reasonably practical experimental approach to the study of the centrifuging of liquid metals.

Inverse Chill

Discussing the subject of inverse chill, he felt that the term "inverse chill" could be used very loosely to cover at least three different types of defects which occurred in iron castings. There was the type of defect where the iron showed some grey structure at the periphery when it was expected to be white, and the type where the iron had some white at the centre when it was expected to be grey, and both were referred to as inverse chill. He had described a form of inverse chill found in undercooled-graphite irons and had pointed out that it had an acicular structure. He believed it was the suggestion of Dr. Riley and Mr. Gillyatt that the inverse chill illustrated in Fig. 13 of their Paper might be of that type.

However, in respect of Fig. 13, one or two points might well be brought out. First, the graphite around the periphery of the specimen was of the more or less normal flake form and not of the undercooled-graphite form. Secondly, slightly below the centre of the left side of Fig. 13 there was a dendrite, which stopped short at the area of the inverse chill, but did not traverse it. He had found on many occasions that if, during the solidification and cooling of a iron, a cavity were created, the likelihood was that phosphorus-rich liquid would be forced into that cavity, and he suggested that Fig. 13 lent strong support to the idea that that was a phosphorus segregation and not inverse chill in the normal sense of the term. His experience of iron/carbon/phosphorus alloys would suggest that that structure represented a phosphorus content of about 3 per cent.; and knowing the analytical difficulties, it might well be that the Authors would find a lower figure due to sampling difficulties.

Sulphur Segregation

Next, he felt that the basic effects of sulphur segregation were not stated very clearly. The formula "percentage manganese = 1.7 × per cent. sulphur + 0.3" was quoted, but it was well to remember that that formula was but a rough rule. It defined the manganese required to prevent sulphur having a discernible chilling effect; it had no theoretical

significance and did not necessarily mean that the sulphur was all present as manganese sulphide. The rule was not intended to indicate the ability of manganese to remove sulphur and so the Authors' contention that it is only partially true is irrelevant. Indeed, if molten iron had stood for any length of time at temperatures of 1,200 to 1,450 deg. C., one must regard most of the sulphur present in the liquid iron as being dissolved as sulphur or iron sulphide. Considerable work had been done on this subject by various workers[1-8] and a great deal was known about the solubility of sulphur in the presence of manganese, silicon and carbon. At a given temperature the amount of sulphur which could dissolve in liquid cast iron depended on the manganese content—the higher the manganese content the lower the sulphur. For a given manganese content the solubility of sulphur in liquid iron decreased with decreasing temperature. Separation of manganese sulphide would only take place if the product of manganese content and sulphur content which was characteristic of a given temperature was exceeded. This product decreased with decreasing temperature.

Desulphurization

Segregation desulphurization by manganese could never go to completion, since sulphur was still soluble in the liquid fraction of the iron even after solidification had begun. Manganese sulphide precipitating during the solidification process was unlikely, even under the most severe conditions, to separate from the metal. Any manganese sulphide occurring in the Authors' samples 258 and 272 was likely to have formed at relatively low temperatures, *i.e.*, under conditions not favourable to complete separation. Even in sample 270 the published data indicated that little separation of manganese sulphide would occur above 1,375 deg. C. approximately. For sample 278, separation might begin at about 1,300 deg. C. Broadly speaking, the results obtained were exactly what might be expected.

The separation of manganese sulphide was a relatively slow process but the technique described by the Authors might be more rapid than had been possible in the past if a method of sampling the metal at each temperature could be devised.

DR. RILEY thanked Mr. Morrogh for his interesting contribution and agreed entirely with what he had said. There were big experimental difficulties and he, too, felt that some of the effects observed were perhaps not due to inverse chill in the sense in which they had been described, but could be due to phosphorus as well, and that was why they had carried out the further experiments reported. He was also fully aware that the phosphorus figures obtained on analysis were probably widely in error because of the difficulty of sampling. There, he would prefer to leave the subject, for they could not be quite certain; but he personally felt that the pressure influence was there and that all the effects obtained could not be explained solely of account of phosphorus segregation.

Mr. Morrogh's detailed explanation of his views of sulphur segregation was warranted criticism. He (Dr. Riley) agreed that the rule referred to was purely an arbitrary method used by foundrymen to calculate optimum manganese content.

As to the temperature used in the experiments, he said the maxima were just over 1,400 deg. C., and in general those were the ones at which the work had been done. The rate of cooling was deliberately varied from as little as 5 deg. per min. over the critical range to something like 60 deg. per min. The sulphur experiments were generally carried out at a rate of cooling of about 40 to 50 deg. per min.

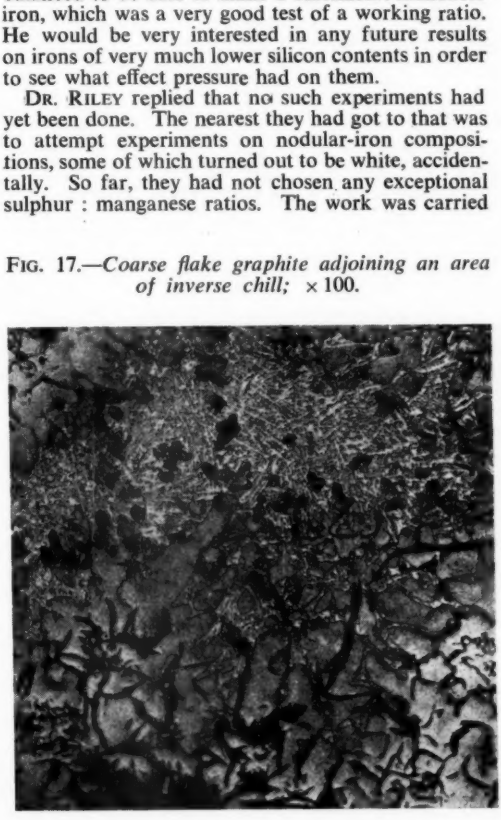
White-iron Compositions

MR. H. G. HALL asked if the Authors had centrifuged in that manner any metal compositions approaching that of white cast iron and, if not, whether they would do a little work in that field. It was a little disappointing that the results given did not take the subject very far. The differences in analyses could almost be those of analytical co-relation between one laboratory and another.

Emphasizing Mr. Morrogh's point about the manganese : sulphur ratio that was quoted, he said that with cast No. 258, having manganese content at 0.25 per cent. and sulphur at 0.094 per cent., he would be perfectly happy that the sulphur was sufficiently balanced to be able to make a blackheart malleable iron, which was a very good test of a working ratio. He would be very interested in any future results on irons of very much lower silicon contents in order to see what effect pressure had on them.

DR. RILEY replied that no such experiments had yet been done. The nearest they had got to that was to attempt experiments on nodular-iron compositions, some of which turned out to be white, accidentally. So far, they had not chosen any exceptional sulphur : manganese ratios. The work was carried

FIG. 17.—*Coarse flake graphite adjoining an area of inverse chill;* × 100.



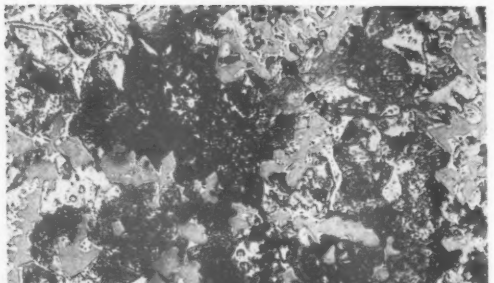


FIG. 18.—*Manganese-sulphide inclusions in top of spun-iron specimen; cast No. 74, Table VI;* ×300.

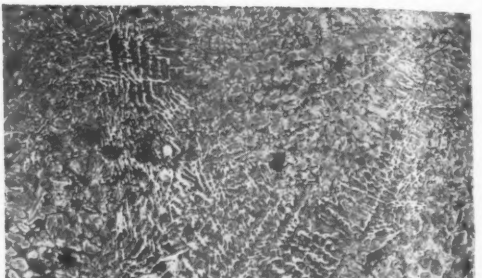


FIG. 19.—*Phosphide agglomerates in spun-iron specimen; cast No. 258, Table VI;* ×50.

out for practical purposes initially and they had not had time to make a lot of experiments on unusual compositions; most of the specimens had a normal sulphur : manganese ratio.

Pressure Effects

MR. J. DEARDEN said it was not clear at what part of the metal that the gravitational force was measured. The value of *g* increased from the bottom to the top of the metal and he presumed the Authors had taken an average value at about the middle.

He asked for information regarding the length of time the metal was molten while under the influence of centrifugal force, since convection currents and segregation effects could only continue while the metal was molten. When the metal reached the semi-solid conditions, segregation ceased. He had noticed that the inverse chill nearly always occurred in the lower part of the metal and this suggested that centrifugal pressure was the predominant effect. He wondered whether inverse chill in actual castings was caused by pressure arising from the formation of blowholes after the casting had developed a strong external shell. Under these conditions, the internal pressure could be very high and evidence of this could sometimes be seen in the form of phosphide sweat on the exterior of the casting.

Centrifugal casting was often regarded as imparting greater density to the metal than could be obtained by normal static methods of casting, and he asked whether the Authors had made density comparisons between statically- and dynamically-solidified cast iron having the same amount of graphite in each case. This should show whether there was any difference in porosity in samples of iron cast by the two methods.

MR. GILLYATT said the gravitational field was measured at the centre of the specimen. The fact that the gravitational field was not the same at the top as at the bottom had not been overlooked. Mechanical considerations prevented the attainment of this ideal. At the present stage they felt they were not justified in overlooking it, and they had kept the facts in mind.

In most cases, the cooling rate was about 15 to 20 deg. per minute and always the metal was held in the molten condition for about 20 min. prior to cooling. That point was made in Table III. The metal was heated to the molten condition and the furnace current was adjusted to keep it at approximately constant temperature. The same point was also brought out in Fig. 9, which gave typical cooling curves for static and spun melts.

Comparative Densities

DR. RILEY, dealing with the question of the comparative densities of statically- and dynamically-solidified metal, said they had made no measurements of the density of the iron specimens after spinning; but, like Mr. Dearden, imagined that centrifuging should produce a denser iron. Some interesting shrinkage effects had been observed in some of the specimens, which he thought tended to bring out that point. In the spun specimens there was often an area of shrinkage in the centre, though, at first consideration, that might appear to be contradictory. They had also found that effect in the white-metal alloys illustrated in Figs. 7(*a*) and 7(*b*). The view was that that central shrinkage took place when the alloy was in the pasty condition after the bulk of the alloy had solidified. Very dense metal had solidified as the shell, but the central area was still pasty and it was in that area alone that the shrinkage occurred. The influence of the large pressures due to centrifug-

ing precluded the possibility of having well distributed gas porosity or micro-shrinkage.

Temperature Measurement

MR. H. P. HUGHES wondered what degree of accuracy the Authors considered they were able to achieve in temperature measurements. According to the figures in Table III it would appear that they were getting to within about 1 deg. C.

With regard to sulphur solubility in ferrite, he asked for the Authors' views on the particular iron they had under consideration, and to what extent did they think it occurred in any other range of irons? Was the figure such as could be accepted as a fixed amount, depending, of course, on the amount of ferrite present in the material ?

He was rather intrigued by the operation of a centrifugal force where convection currents were also present, and their reconciliation might be an important difficulty in trying to interpret the results. Surely the two forces must have effect upon each other when they were in operation at one and the same time.

The segregation of manganese sulphide was very interesting. Mr. Morrogh had said he considered that the temperatures were not adequate to produce the conditions described, but Mr. Hughes wondered whether one should consider the atmospheric forces that were applied as well as the temperature ; the whole system might have different effect in the production of segregation.

MR. GILLYATT, dealing with the query concerning temperature measurement, said this was done by a potentiometer and the Authors claimed a measured accuracy within 1 deg. C. at temperatures in the region of 1,000 deg. C. This was exclusive of the

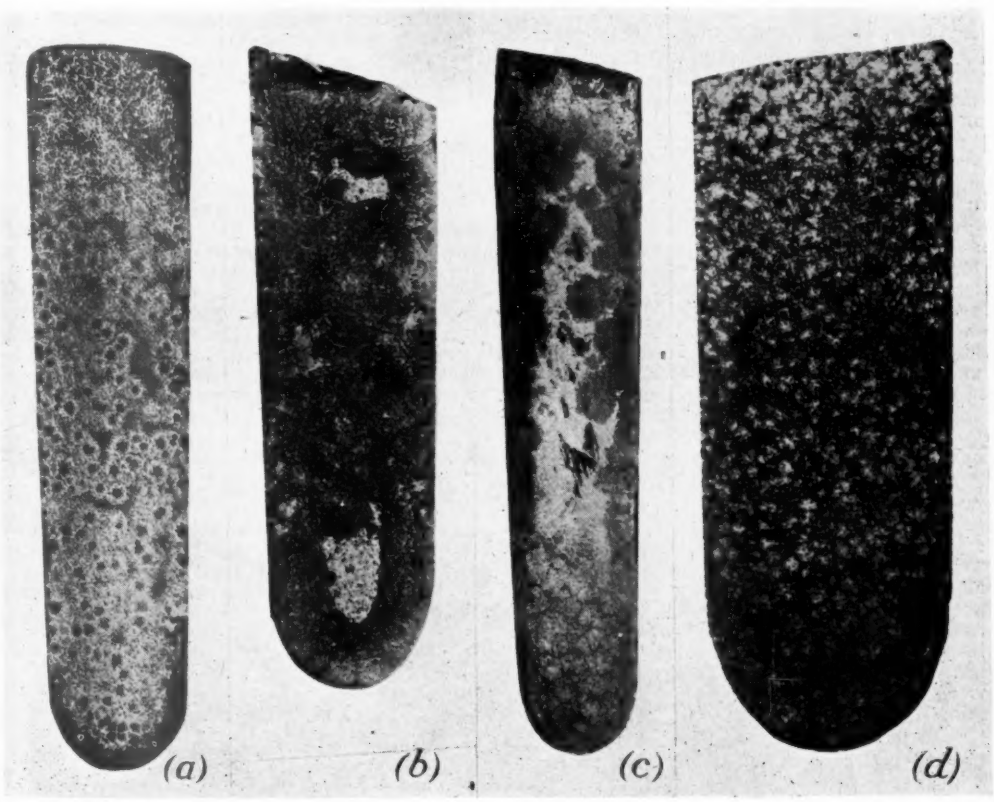
FIG. A.—*Structure of samples prepared in additional experiments to check mechanism of formation of inverse chill.*

(*a*) Low-phosphorus iron, static melt : total carbon 3.44; silicon 3.7; manganese 0.2 per cent.; rate of cooling : 46 deg. C. per min.

(*b*) Composition as (*a*), but specimen spun at 1,000 g.; rate of cooling : 50 deg. C. per min.; check composition of specimen after spinning : total carbon 3.16; silicon 3.57; sulphur 0.029; manganese 0.21 per cent.; phosphorus content : hard area—0.17; soft area—0.12 per cent.

(*c*) High-phosphorus iron (cast No. 258, Table VI), showing inverse-chill area after spinning at 1,000 g.; total carbon 3.3; silicon 2.35; sulphur 0.094; phosphorus 1.25 and manganese 0.25 per cent.; rate of cooling 57 deg. C. per min.

(*d*) Same specimen as (*c*) but top ½-in. of ingot removed and re-melted statically; rate of cooling 49 deg. C. per min.; no inverse-chill area found.



time lag in the passing of the heat from the molten iron inside the crucible to the outside. From the metallurgical point of view, it would have been impossible to have had the thermocouples inside the metal, much as it might have been preferable. As to convection currents and centrifugal force, so far as he could see, one would expect the convection currents to be perhaps not in direct proportion to the gravitational field, but at least to increase with increased gravitational field.

Work on MnS/Fe System

DR. RILEY, commenting on Mr. Hughes' reference to manganese-sulphide segregation, said that the question could best be answered by Mr. Morrogh.

MR. MORROGH, re-stating his viewpoint on that matter, said the segregation of manganese sulphide from iron melts had been studied with considerable precision by a group of workers—Joseph and Holbrook in America, Oelsen in Germany and Chipman in America—and it had been found that when working under conditions approaching equilibrium at any one temperature the product manganese sulphide was a constant. If the product, manganese × sulphur, were above the value which was characteristic of that particular temperature, then separation of manganese sulphide occurred. If then the temperature was lowered, more manganese sulphide separated, and that was a process continuing down to the solidification temperature.

In the experiments described in the present Paper, the Authors had had to allow the material to solidify in the crucible, and they had, as it were, the sum total of the effects of the separation of manganese sulphide at all the temperatures from the highest down to the solidification temperature. He wanted to point out to them that their experimental technique was essentially a more refined tool than that available to other workers and it would provide information of considerable academic interest if they were able to hold melts, for instance, at 1,400 deg. C. and measure the manganese and sulphur content, then hold them at 1,300 deg. C. and do the same thing, and arrive at some quantitative data which metallurgists should be able to understand.

DR. RILEY said he might have to suggest that Mr. Gillyatt should provide some quenching arrangement in addition to the other controls which were operated.

THE CHAIRMAN commented that foundrymen were rather inclined to think in terms of the constituents of the cast iron as viewed under the microscope after it had cooled to room temperature instead of what was happening in the molten condition. If all the constituents were in full solution one would not expect any separation, and thus had to apply the technique within the extremely narrow temperature range between solidus and liquidus. It seemed that for positive results, it was necessary to continue the work in a very narrow temperature band and he asked if the Authors agreed.

DR. RILEY said he did ; and everything pointed to the fact that the work had to be carried further.

THE CHAIRMAN expressed the appreciation of the meeting to the Authors for their most interesting Paper, and wished them every success in the continuation of the work.

WRITTEN COMMENT

MR. A. PRINCE (University, Southampton) wrote that there were two points which he would like to raise with regard to this Paper: (1) Could the Authors give details of the electro-erosion technique which they used in the sectioning of some of the centrifugally-cast specimens?; (2) This relates to the microstructure of the Sn/Pb/Sb/Cu alloy centrifuged at the equivalent of 1,000 g. Figure 7 (b) in the Paper shows that the separation of the cuboids, under 1,000 g, is not as would be expected if the only effect to be considered is the relative densities of the cuboids and the matrix phase. There is, for instance, a segregation of cuboids—and probably also of the star-shaped η Cu/Sn phase—to both top and bottom of the crucible. Although the Authors say that "at 1,000 g. the process of flotation was far from complete," they do not give any explanation in the Paper for the rather startling behaviour of this alloy when solidified at 1,000 g. Probably they would like to comment on the influence of temperature gradients on the distribution of the less-dense phase, although such gradients as exist at temperatures of 350 to 360 deg. C. will probably be far less than those existing when casting irons at temperatures some 1,000 deg. C. higher.

In reply, the AUTHORS wrote:—The electro-erosion method of machining has been frequently described in the literature* and they would gladly give Mr. Prince full details of their method privately.

For reasons given in the Paper it has proved impossible to calculate the magnitude of all the thermal currents to be expected in the crucible and it was also impossible to measure these. Without doubt, the anomalous behaviour of the cuboids in the antimony/tin alloy was due to the thermal currents which interfered with the expected separation of phases viewed from the standpoint of differences in specific gravity only. The Authors incline to the view, also, that any difference found at 350 or 360 deg. C. would be present also at the higher temperatures and of perhaps greater magnitude.

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* Notes on Policy and Development in the U.S.A. in Novel Machining Methods. Involving the Conservation of Diamond Boart, by A. J. Chisholm, British Commonwealth Scientific Office (North America) 1800, "K" Street N.W., Washington D.C.

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† Quoted in discussion by Mr. Morrogh.

News in Brief

THE *Bureau International de la Récupération* (B.I.R.) is organizing a conference to be held in Paris from September 22 to 24.

WILKINS & MITCHELL, LIMITED, Darlaston, have made a 400-ton panel press for exhibition at the fourth European Machine-tool Exhibition at Milan in September.

OVER 4,000 visitors went to the British Railways Carriage and Wagon works on an open day held to celebrate the centenary of the North Eastern Railway.

IN THE WINTER'S TRIAL of influenza vaccine, which is being organized by the Medical Research Council, two hundred employees of the Butterley Company, Limited, Ripley, have volunteered to act as "guinea pigs."

A £1,700,000 CONTRACT has been secured by Crompton Parkinson, Limited, the parent company of Derby Cables, Limited, of Alfreton Road, Derby, to supply electric cable and copper conductors to the Russian Government. This contract will be completed entirely at the Derby works.

A CONFERENCE on the employment of persons in advanced age groups is being organized by the Royal Institute of Public Administration in conjunction with Birmingham University (at the University) on September 28. It will be opened by Lord Amulree, president of the Medical Society for the Care of the Elderly.

AN AGREEMENT has been concluded with J. M. Voith G.m.b.H., Heidenheim/Brenz, Germany, under which Brown Brothers & Company, Limited, Rosebank Iron Works, Edinburgh, will manufacture, under licence, the Voith-Schneider propeller and control equipment and supply all requirements within the British Commonwealth.

A HELICOPTER SERVICE ferrying buyers from Prestwick or Renfrew airport direct to Kelvingrove, Glasgow, to the Scottish Industries Exhibition is planned by the exhibition authorities. Landing point will probably be in Kelvingrove Park. An exhibition official said that the plan is being discussed with B.E.A. He said: "If we can get over the practical difficulties it is likely the plan will materialize."

TO ASSIST SMALLER MANUFACTURERS to reduce handling costs the materials handling sub-committee of the Institution of Production Engineers is organizing a one day conference in Birmingham on October 23 at which well-known authorities will speak. The conference is to be held at the premises of John Wright and Company (Radiation) Limited. There will be an exhibition showing methods of handling applicable to certain industries.

AT THE BAGHDAD TRADE FAIR (October 25 to November 8) British Insulated Callender's Cables are exhibiting on stand 135 a comprehensive range of electrical equipment, high-, medium- and low-voltage cables and accessories, copper busbars and power capacitors. Other items will include current-collection equipment for cranes and conveyors. The stand will also feature Callender-Hamilton bridges, six of which, valued at £69,000, were ordered recently by the Iraq Development Board.

AN IMPORTANT PART in the recent contract received in Scotland from the Sudan Government for oil-fired locomotives is being carried out by the Edinburgh firm of Laidlaw, Drew & Company, Limited. This firm is supplying the steam-jet-type, oil-burner units for the locomotives. It has already supplied the units for the first 22 locomotives, and expects to receive the order to proceed with the next 20 shortly. The firm has supplied steam-jet oil-firing equipment of similar design for locomotives throughout the world.

THE INSTITUTION OF ELECTRICAL ENGINEERS is to celebrate the jubilee of the thermionic valve on November 16—50 years exactly from the date of the application by Sir Ambrose Fleming for the British patent for his thermionic valve. The proceedings will be opened by the Marquess of Salisbury, Lord President of the Council, and three lectures will be delivered, one each by Sir Edward Appleton, F.R.S., Prof. G. W. O. Howe, and Dr. J. Thomson. An exhibition of historical apparatus will be held at the institution in association with the celebration.

WHEN HE SPOKE at the celebration dinner on August 14 held to commemorate the 25th anniversary of the founding of Loxdale Foundries, Limited, Bilston, Mr. Edwin Pitt, the managing director, who established the firm 25 years ago, warned his employees of a "struggle that lies ahead." He told them that the firm has been finding things increasingly hard. "We have to bear the brunt of rising prices such as fuel and iron. We are being undercut from abroad and there is nothing I can do. My customers cannot stand another increase in our costs," he said.

THE BRITISH ELECTRICITY AUTHORITY hopes to be able to plan, among other projects within the next few years, a large atomic power station employing standard 60,000 kw. generating units. This is stated in a booklet, "Power and Prosperity," published by the authority, price 1s. The booklet, after tracing the historical development of the industry, indicates the progress made in recent years, reveals future plans to meet the ever-growing demand for power, and concludes with a financial survey indicating the necessity for increasing the electricity supply industry's borrowing powers.

FOUNDERS operating electric furnaces will be interested in the performance in practice of a selectively-refined mineral-oil and a compatible oxidation inhibitor produced by Shell-Mex and B.P., Limited, Shell-Mex House, Strand, London, W.C.2, for use in transformers. The results obtained by the use of Diala Oil B.X. in many individual transformers, both in respect of non-development of acidity and continued resistance of the oil in oxidation, have been reported to be most satisfactory. A number of important users have now had transformers in service with this oil for over four years without attention.

THE 146-YEAR-OLD Midland lock and safe making firm of Chubb and Sons hopes soon to put on the market, at a cost only half that now asked, a safe which will be made of the secret alloy known as the anti-blowpipe alloy. The alloy was first introduced into strong-room construction about 30 years ago but recent research and development has considerably improved it. It is stated that attempts to blow safes made of the alloy and with an improved re-locking device, only succeed in making the lock more defiant. Chubbs believe that, in safes costing from £300 to £500, they will be able to give buyers the protection that has hitherto been twice as costly.

THE IMPORT DUTIES on certain iron and steel products are temporarily suspended until September 18, 1954, by the Import Duties (Exemptions) (No. 3) Order, 1954. After consultations with the Iron and Steel Board, Her Majesty's Government have decided to continue to suspend the import duties on the same

News in Brief

products for six months until March 18, 1955, but the period for which the duty is suspended on cold-rolled steel sheets of a value of less than £80 per ton will be one year, until September 18, 1955. The Order giving effect to this is the Import Duties (Exemptions) (No. 6) Order, 1954 (S.I. 1093); copies of which may be obtained from H.M. Stationery Office or any bookseller (price 3d.).

A NEW FASTENING for securing flat-bottom rails to concrete sleepers which, it is understood, will make travel smoother, prolong the life of the sleepers, and help to check rail creep, has been designed by British Railways. The fastening consists of two steel clamps which are secured into wooden plugs in the concrete sleeper and grip the foot of the rail on each side. Rubber pads, which go between clamps and rail and sleeper, absorb vibration and also provide electrical insulation of the rails. The new fastenings will be installed experimentally in the autumn on a selected length of track, and if this is successful it may enable the use of concrete sleepers in main lines to be greatly extended.

THE DISTILLERS COMPANY, LIMITED, announce that negotiations have recently been concluded with the Dow Chemical Company of Michigan, U.S.A., to form a British company with the name Distrene Limited. The object of the new company, in which Distillers will hold the controlling interest, is to manufacture at Barry, South Wales, polystyrene and modified polystyrenes under the Dow company's Patents. British Resin Products, Limited, a wholly-owned subsidiary of Distillers, will be appointed sole selling agents for the new company. The directors of Distrene Limited, nominated by Distillers are:—Major C. J. P. Ball, Mr. H. H. Woolveridge, Mr. P. A. Delafield, Dr. J. J. P. Staudinger, and by Dow Chemical:—Mr. N. R. Crawford, Dr. William H. Schuette, Mr. A. E. Young.

MR. EDWARD TURNER, managing director of the Triumph Engineering Company, Limited, has returned from a business trip to the United States, where he has been to launch the firm's 1955 programme of motor-cycle models. "We have to sell every inch of the way," he commented. On other aspects of the American scene, he commented on the much easier transport facilities in the U.S.A. due to better roads. Our inadequate road system is increasingly cramping our industrial effort, he said. The roads are "clogged arteries" impeding the nation's export programme. On comparative cost-of-living values, Mr. Turner said that although the British workman had a higher standard of living to-day, it was only "buns and tea" compared with Americans.

POWER for the British North Greenland Expedition, members of which have recently returned to this country, was provided by a Petter AV1 water-cooled Diesel generator set, which was used for light and communication with the outer world during months of intense darkness and cold. One of the two sets originally provided was lost when a lighter transporting equipment across Britannia Lake capsized, so that the entire load had to be borne by the surviving set for the greater part of the time during the first year. Petters, Limited, also provided an AVA-type, air-cooled Diesel engine which was used in an unheated annexe to the generator room to keep starting temperatures down to minus 40 deg. F. Useful information was obtained on the operation for long periods of this type of engine under severe conditions.

Personal

MR. S. T. JAZWINSKI has been appointed director of research, Barium Steel Corporations subsidiaries.

Mr. B. HAZELL has been appointed chairman of the East and West Ridings Regional Board for Industry in succession to Mr. G. H. BAGNALL, who has resigned.

GEO. W. KING, Limited, announce the appointment of MR. DONALD M. KING as chairman of the company. He succeeds MAJOR A. C. HERRING, V.C., who remains a director.

Mr. C. F. PRICE, a director of Charles Thomas & Company, Limited, edge-tool manufacturers, of Aston, Birmingham, has been co-opted a member of the Royal Metal Trades Pension and Benevolent Society.

Mr. K. L. STRETCH has been appointed works manager at Calder Hall, Sellafield (Cumberland), where the first atomic power station in Britain is being built. Mr. Stretch, who will take up his appointment later in the year, is at present with Imperial Chemical Industries, Limited. He is an M.A., a barrister-at-law, and an associate member of the institutes of Civil, Mechanical, and Electrical Engineering. He is 37.

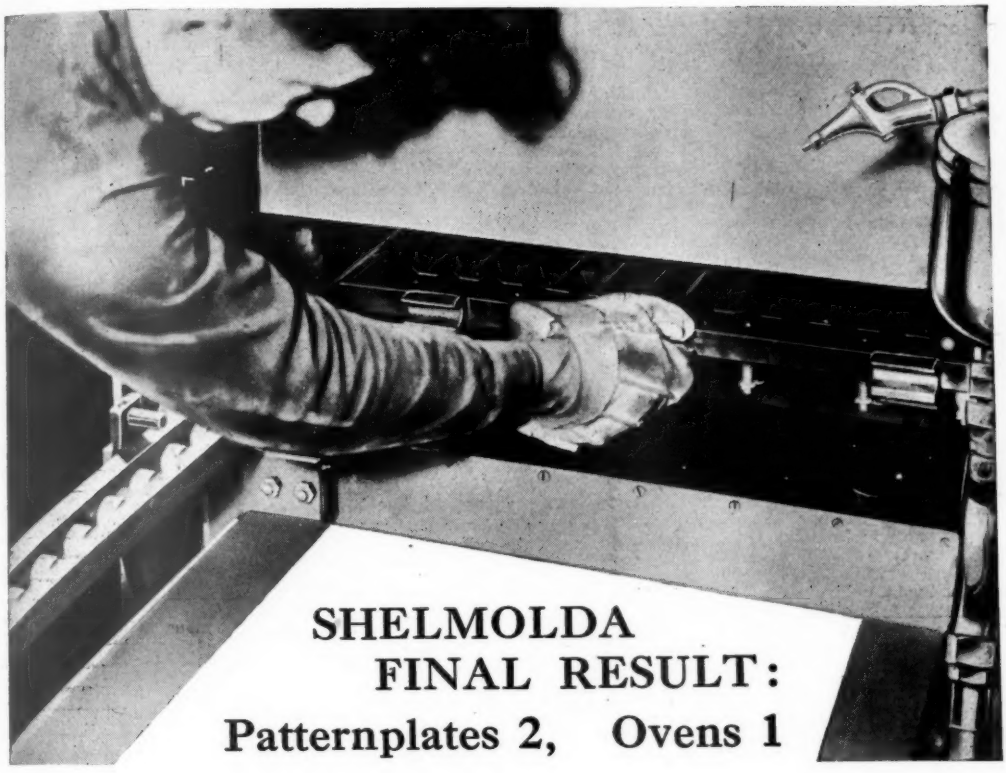
MR. H. J. G. GOYNS of D. Drury & Company, Limited, Johannesburg, left South Africa on August 17 on a visit to the United Kingdom, with the object of studying recent developments in the fields of melting plant, foundry and rolling-mill equipment. Following a period at the works of Davy & United, and the Electric Furnace Company, he will be spending some time in foundry and engineering shops in Sheffield, Birmingham, Manchester and Wales. Mr. Goyns is the immediate past-president of the South African branch of the Institute of British Foundrymen, and vice-president of the South African branch of the Institution of Production Engineers.

Obituary

THE DEATH took place recently of Mrs. Wood, the wife of Mr. D. H. Wood, a past-president of the Institute of British Foundrymen. It will be remembered that Mrs. Wood was assiduous in attendance at foundry functions both national and international.

Mr. L. W. BARBER, who died recent at the age of 75, was a well-known figure in industrial circles of the Midlands. In 1908, he founded the Midland Electric Manufacturing Company, Limited, Birmingham, with less than 10 employees, and the company, now employing 1,500 people, is one of the largest of its kind in the Midlands. Mr. Barber was managing director for over 30 years, and more recently was chairman of the company.

IT IS REPORTED that Mr. Charles Abraham Starling of Norwich, died recently. Mr. Starling retired four years ago after being with Barnards Limited in continuous employment for over 50 years, for 30 of them as foundry manager. When he began his career with the company, the work consisted chiefly of making castings for stoves, mantels, etc. From 1906, a greater proportion of heavy castings was included in the output. Between the wars and after the last war, the foundry made many castings for use in Norwich industry, in fact, there are very few firms in the city without some equipment with the making of which Mr. Starling was concerned. A keen bowler, Mr. Starling was a former county player and, in his younger days, an enthusiastic cricketer.



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It's a winner, right enough, and here's why:

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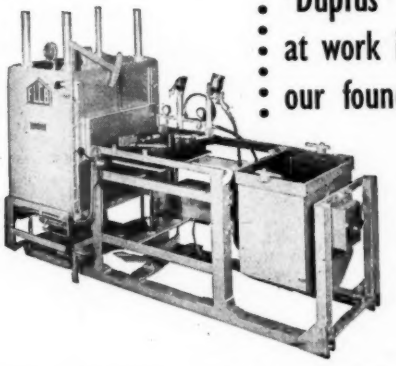

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Raw Material Markets

Iron and Steel

Pig-iron production is being maintained at maximum levels. The raw material position remains satisfactory, particularly in regard to iron ore, deliveries of which from both home and overseas sources are sufficient to meet current requirements and to augment stocks.

Enough blast-furnace coke is forthcoming to burden the furnaces, but deliveries have not added appreciably to stocks and increased quantities will be required later in the year when furnaces now in the course of construction or rebuilding will be brought into commission.

The steelworks are taking up all available supplies of home-produced basic pig-iron, but they continue to depend to some extent on imported iron. The new blast-furnace units will eventually provide additional tonnages of pig-iron for the steelworks, most of them being scheduled for the production of this grade of iron. The foundries are also able to relieve the furnaces of most grades of pig-iron and they are, in fact, experiencing difficulty in obtaining some irons of their choice. The low- and medium-phosphorus pig-irons in particular are scarce, and the engineering and speciality foundries could utilize much more than they can obtain. Hematite is also in short supply, chiefly in the higher silicon ranges. High-phosphorus pig-iron, used mostly by the light, jobbing, and textile foundries, is generally satisfying present demands.

The engineering and speciality foundries have good order-books, while many of the jobbing and textile foundries have a fair amount of work on hand, and in some areas business at the light foundries, where short-time working has been experienced for some time, is tending to improve.

The foundries are able to obtain their scrap requirements without much difficulty. Ganister, firebricks, and limestone are readily forthcoming. Supplies of some grades of Welsh foundry coke are stringent, but, on the whole, foundry coke is coming forward steadily.

The products of the re-rollers are in much bigger demand than they have been for some time. There is a good market for steel strip; makers are fully booked for some months ahead and are unable to accept additional orders other than for deferred delivery. Re-rollers of small bars and light sections have also benefited by the improved trading conditions and in most instances are now able to programme for a full week's work. Home demands are maintained, while orders from abroad, chiefly from Commonwealth countries, have considerably improved the outlook.

The sheet re-rollers are also receiving good demands for their outputs of both black and galvanized sheets. The improved business has increased the demand for steel semis in billets, blooms, and slabs; so far, home steelworks have been able to satisfy requirements without incurring the need for increased supplies of imported material.

Non-ferrous Metals

The details of consumption and stocks for the month of June issued by the British Bureau of Non-Ferrous Metal Statistics make a good showing, the figure for copper consumption being particularly encouraging. This amounted to no less than 49,474 tons, of which 37,109 tons were virgin, and showed an increase of about 2,200 tons over May. For the half year the total was 277,835 tons, compared with 219,782 tons in the corresponding period last year. Stocks of virgin copper at June 30 were about 2,700 tons up, at 68,037 tons. In zinc the trend of usage was also upwards, 29,665 tons of all grades comparing with 27,551 tons in May. Stocks of virgin zinc, at 40,389 tons, were about 2,000 tons up. Lead stocks advanced slightly to 30,437 tons, while consumption, all grades, at 28,574 tons, was virtually unchanged. In tin there was an upward movement in our consumption to 1,860 tons, while stocks, at 4,075 tons, were slightly lower.

The American copper statistics for July show a drop of 11,600 tons in blister production to 73,800 short tons and of 5,000 tons in refined to 107,100 tons. Deliveries, at 97,500 tons, were down by 8,800 tons. Stocks of refined copper were 68,921 tons. Outside the United States production was up in comparison with June, crude by 7,700 short tons, at 132,500 tons, and refined by 17,200 tons, at 105,800 tons, but there was a big drop—no less than 25,000 tons—in deliveries, which totalled 105,200 tons. Stocks of refined copper at July 31 stood at 170,550 short tons, a drop of about 10,000 tons on June 30.

Nothing spectacular occurred on the Metal Exchange last week, trading being quiet. Copper gained £2 10s. for cash and £2 for three months, the news of strikes at Kennecott's properties in Chile and the United States imparting a firm tone to the market. Zinc closed 5s. up for August, but unchanged for November, while lead improved by £1 for the forward position. Tin closed £2 10s. up for cash and three months. It has been announced that additional purchases by the U.S. Government of lead and zinc for the stockpile are to be made on a long-term basis, but no change will be made in the import duties on these metals.

Official metal prices were as follow:—

COPPER, Standard—*Cash:* August 19, £236 10s. to £237; August 20, £236 15s. to £237; August 23, £237 5s. to £237 15s.; August 24, £239 5s. to £239 10s.; August 25, £240 to £240 5s.

Three Months: August 19, £235 10s. to £235 15s.; August 20, £235 5s. to £235 10s.; August 23, £236 7s. 6d. to £236 10s.; August 24, £237 10s. to £237 15s.; August 25, £237 15s. to £238.

TIN, Standard—*Cash:* August 19, £730 to £731; August 20, £728 to £729; August 23, £731 to £732; August 24, £731 10s. to £732; August 25, £732 to £733.

Three Months: August 19, £729 to £730; August 20, £728 to £729; August 23, £730 to £731; August 24, £731 to £732; August 25, £731 to £732.

ZINC—*August:* August 19, £74 15s. to £74 17s. 6d.; August 20, £74 10s. to £74 15s.; August 23, £76 17s. 6d. to £77; August 24, £77 5s. to £77 15s.; August 25, £78 to £78 10s.

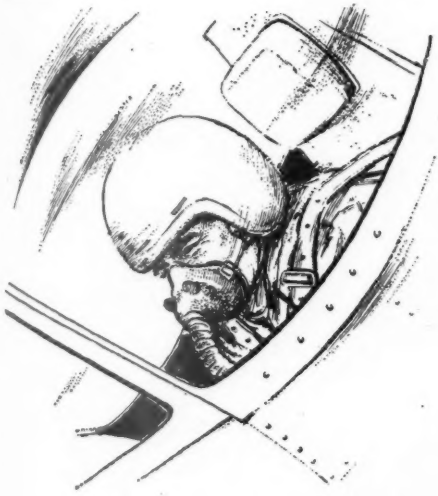
Second half November: August 19, £74 15s. to £74 17s. 6d.; August 20, £74 10s. to £74 15s.; August 23, £76 17s. 6d. to £77 2s. 6d.; August 24, £77 10s. to £77 15s.; August 25, £78 to £78 5s.

LEAD—*Second half August:* August 19, £97 15s. to £98; August 20, £97 5s. to £97 10s.; August 23, £98 5s. to £98 10s.; August 24, £98 15s. to £99; August 25, £99 15s. to £100.

Second half November: August 19, £95 to £95 10s.; August 20, £95 to £95 5s.; August 23, £96 15s. to £97; August 24, £97 to £97 10s.; August 25, £97 15s. to £98 5s.

Corrosion Advice Bureau

The British Iron and Steel Research Association has formed a Corrosion Advice Bureau in order to deal adequately with the numerous inquiries that are received for advice on the prevention of corrosion of ferrous metals. The bureau will be at 140, Battersea Park Road, London, S.W.11 (telephone: MACaulay 5511).



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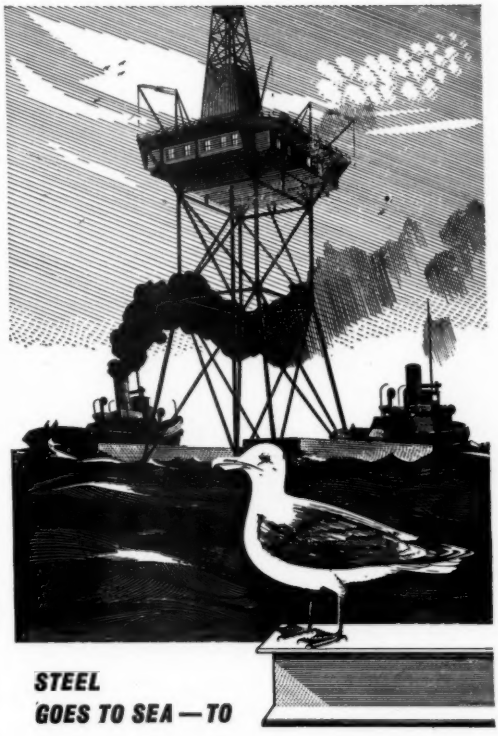

STEEL GOES TO SEA — TO

SEARCH FOR COAL

BRITISH MINING engineers will soon be boring for coal that lies under the sea.

A 170 foot high steel tower, which is an outcome of the wartime Maunsell sea-fort, is to be built, towed out to sea and lowered until its base rests on the sea-bed. The drilling crews will live and work on the deck of the tower, using a special rig capable of boring over half a mile into the bed of the sea. When one bore is completed the tower will be refloated and towed to the next location.

Much of Britain's future coal supply must come from under the sea. This is one of the ways in which steel is helping to ensure that supply. Last year approximately 600,000 tons of steel were used by the National Coal Board.

STEEL is at your service

THE BRITISH IRON & STEEL FEDERATION 5.78

Current Prices of Iron, Steel, and Non-ferrous Metals

(Delivered unless otherwise stated)

August 25, 1954

PIG-IRON

Foundry Iron.—No. 3 IRON, CLASS 2:—Middlesbrough, £14 19s. 6d.; Birmingham, £14 12s. 9d.

Low-phosphorus Iron.—Over 0.10 to 0.75 per cent. P, £17 5s. 9d., delivered Birmingham. Staffordshire blast-furnace low-phosphorus foundry iron (0.10 to 0.50 per cent. P, up to 3 per cent. Si), d/d within 60 miles of Stafford, £17 16s. 9d.

Scotch Iron.—No. 3 foundry, £17 9s. 6d., d/d Grangemouth.

Cylinder and Refined Irons.—North Zone, £18 19s. 6d.; South Zone, £19 2s. 0d.

Refined Malleable.—P, 0.10 per cent. max.—North Zone, £19 19s. 6d.; South Zone, £20 2s. 0d.

Hematite.—Si up to 2 per cent., S. & P. over 0.03 to 0.05 per cent.:—N.-E. of England (local iron), £17 14s. 6d.; Scotland (Scotch iron), £18 1s. 0d.; Sheffield, £18 19s. 0d.; Birmingham, £19 6s. 6d.; Wales (Welsh iron), £18 1s. 0d.

Basic Pig-iron.—£15 10s. 6d. all districts.

FERRO-ALLOYS

(Per ton unless otherwise stated, delivered)

Ferro-silicon (6-ton lots).—40/55 per cent., £42 0s. 0d., basis 45 per cent. Si, scale 17s. per unit; 70/84 per cent., £65 0s. 0d., basis 75 per cent. Si, scale 18s. per unit.

Ferro-vanadium.—50/60 per cent., 23s. 8d. to 25s. 0d. per lb. of V.

Ferro-molybdenum.—65/75 per cent., carbon-free, 10s. 0d. per lb. of Mo.

Ferro-titanium.—20/25 per cent., carbon-free, £185 9s. 0d. to £195 0s. 0d. per ton; 38/40 per cent., £251 0s. 0d. to £270 0s. 0d. per ton.

Ferro-tungsten.—80/85 per cent., 13s. 7d. per lb. of W.

Tungsten Metal Powder.—98/99 per cent., 16s. 7d. per lb. of W.

Ferro-chrome (6-ton lots).—4/6 per cent. C, £75 0s. 0d. to £80 0s. 0d., basis 60 per cent. Cr, scale 25s. 0d. per unit; over 6 per cent. C, £74 0s. 0d. to £76 0s. 0d., basis 60 per cent. Cr, scale 24s. 0d. per unit; max. 2 per cent. C, 1s. 7½d. per lb. Cr; max. 1 per cent. C, 1s. 8d. per lb. Cr; max. 0.15 per cent. C, 1s. 9½d. per lb. Cr; max. 0.10 per cent. C, 1s. 9¾d. per lb. Cr; max. 0.06 per cent. C, 1s. 10d. per lb. Cr.

Metallic Chromium.—98/99 per cent., 6s. 6½d. to 7s. 1d. per lb.

Metallic Manganese.—93/95 per cent., carbon-free, £225 0s. 0d. to £232 0s. 0d. per ton; 96/98 per cent., £255 0s. 0d. to £262 0s. 0d. per ton.

Ferro-columbium.—60/75 per cent., Nb + Ta, 52s. 6d. to 70s. 0d. per lb., Nb + Ta.

Ferro-manganese (home).—78 per cent., £54 15s. 0d.

SEMI-FINISHED STEEL

Re-rolling Billets, Blooms, and Slabs.—BASIC: Soft, u.t., £25 12s. 6d.; tested, 0.08 to 0.25 per cent. C, £26 12s. 6d.; hard (0.41 to 0.60 per cent. C), £28 0s. 0d.; silico-manganese, £33 16s. 0d.; free-cutting, £28 16s. 6d. SIEMENS MARTIN ACID: Up to 0.25 per cent. C, £32 12s. 0d.; silico-manganese, £34 17s. 6d.

Billets, Blooms, and Slabs for Forging and Stamping.—Basic, soft, up to 0.25 per cent. C, £29 16s. 0d.; basic, hard, over 0.41 up to 0.60 per cent. C, £30 16s. 0d.; acid, up to 0.25 per cent. C, £33 0s. 0d.

FINISHED STEEL

Heavy Plates and Sections.—Ship plates (N.-E. Coast), £31 1s. 6d.; boiler plates (N.-E. Coast), £32 9s. 0d.; floor plates (N.-E. Coast), £32 10s. 6d.; sectional material N.-E. Coast, £29 4s. 6d.

Small Bars, Sheets, etc.—Rounds and squares, under 3 in., untested, £32 7s. 0d.; flats, 5 in. wide and under, £32 7s. 0d.; hoop and strip, £33 9s. 0d.; black sheets, 17/20 g., £42 1s. 0d.; galvanized corrugated sheets, 24 g., £51 8s. 6d.

Alloy Steel Bars.—1 in. dia. and up; Nickel, £53 8s. 0d.; nickel-chrome, £75 2s. 0d.; nickel-chrome-molybdenum, £84 13s. 6d.

NON-FERROUS METALS

Copper.—Cash, £240 0s. 0d. to £240 5s. 0d.; three months, £237 15s. 0d. to £238 0s. 0d.; settlement, £240 5s. 0d.

Copper Tubes, etc.—Solid-drawn tubes, 27¾d. per lb.; wire, 263s. 6d. per cwt. basis; 20 s.w.g., 294s. 9d. per cwt.

Tin.—Cash, £732 0s. 0d. to £733 0s. 0d.; three months, £731 0s. 0d. to £732 0s. 0d.; settlement, £733 0s. 0d.

Zinc.—August, £78 0s. 0d. to £78 10s. 0d.; second half November, £78 0s. 0d. to £78 5s. 0d.

Zinc Sheets, etc.—Sheets, 15 g. and thicker, all English destinations, £105 5s. 0d.; rolled zinc (boiler plates), all English destinations, £102 15s. 0d.; zinc oxide (Red Seal), d/d buyers' premises, £96 0s. 0d.

Lead (Refined Pig).—Second half August, £99 15s. 0d. to £100 0s. 0d.; second half November, £97 15s. 0d. to £98 5s. 0d.

Brass Tubes, etc.—Solid-drawn tubes, 22½d. per lb.; rods, drawn, 32¼d.; sheets to 10 w.g., 256s. 0d. per cwt.; wire, 30d.; rolled metal, 242s. 3d. per cwt.

Brass (Brazing).—BS1400, B3 (65/35), £165; B6 (85/15), £204; BS249, £174.

Brass (High Tensile).—BS1400, HTB1 (30 tons), £201; HTB2 (38 tons), £210; HTB3 (48 tons), £220.

Gunmetal.—RCH, 3/4 per cent. tin, — ; BS1400, LG2 (85/5/5/5), £199; LG3 (86/7/5/2), £208; G1 (88/10/2/½), £277; (88/10/2/1), £270.

Phosphor Bronze.—BS1400, PB1 (AID released), £289 per ton.

Phosphor Bronze Strip, etc.—Strip, 363s. 3d. per cwt.; sheets to 10 w.g., 385s. 9d. per cwt.; wire, 45½d. per lb.; rods, 39½d.; tubes, 37¾d.; chill cast bars: solids 40d., cored 41d. (CHARLES CLIFFORD, LIMITED.)

Nickel Silver, etc.—Rolled metal, 3 in. to 9 in. wide × 0.056, 3s. 1¾d. per lb.; round wire, 10g. in coils (10 per cent.), 3s. 7d.; special quality turning rod, 10 per cent., ½ in. dia., in straight lengths, 3s. 6d. All prices are net.

Other Metals.—Magnesium, ingots, 2s. 3d. per lb. Antimony, English, 99 per cent., £210 0s. 0d. Quicksilver, ex-warehouse, £100 0s. 0d. Nickel, £483 0s. 0d. Aluminium, ingots, £156 0s. 0d.; aluminium bronze (BS1400), AB1, £250; AB2, £260, Solder, brazing, BS1845, 1s. 11d. lb.; granulated, 2s. 2d. lb.

Recent Wills

PRICE, THOMAS, a director of Dudley Iron & Steel Company, Limited £19,611

BRAIN, LEONARD, a director of Hale & Hale (Tipton), Limited, ironfounders £7,674

CHRISTIE, DAVID, former foundry proprietor, of Ballymena (Co. Antrim) £13,860

SMITH, H. H., formerly chief cost accountant of Ley's Malleable Castings Company, Limited, Derby ... £4,976

CASS, F. R., a director of F. R. Cass, Limited, engineers and ironfounders, of Bury (Lancs) ... £96,996

DAGLISH, G. G., marine consulting engineer, who was formerly with Cammell Laird & Company, Limited, Birkenhead £1,855

HALE, JACK, a director of J. H. Heaton, Limited, domestic machinery manufacturers and ironfounders, of Keighley (Yorks) £14,548

KINNELL, J. L., former chairman and managing director of Chas. P. Kinnell & Company, Limited, ironfounders and heating engineers, of London, S.E.1 ... ... £49,006

THORNEYCROFT, WALLACE, a former president of the Institution of Mining Engineers and a well-known figure in the iron and steel and coal industries £287,779

Forthcoming Events

SEPTEMBER 1

Incorporated Plant Engineers

Leicester branch:—"The Works Engineer and the Factories Act," by H.M. District Inspector of Factories, 6.30 p.m., at the Bell Hotel.

Institution of Production Engineers

Nottingham section:—Visit to the Stanton Ironworks Company, Limited, near Nottingham.

SEPTEMBER 4

Incorporated Plant Engineers

Merseyside and North Wales branch:—Outing and works visit to Josiah Wedgwood & Sons, Limited, at Darlaston.

Yorkshire Flood Damage

The foundry of the Brightside Foundry and Engineering Company, Limited, Ecclesfield, Sheffield was flooded to a depth of four feet in the course of a heavy storm over South Yorkshire on August 20. A stream which flows through the works overflowed just before the bottoms of the four cupolas were due to be dropped. The explosion which would have resulted had the hot coke and slag fallen into the water, endangering 200 men, was averted. A fire tender arrived an hour after the beginning of the emergency and pumped for three hours to clear the foundry area of water. During the emergency, two ladles of molten metal were held in suspension in mid-air. The storm also cut off all electricity supply to the works.

An arc furnace was put out of action in the melting shop of Thos. Firth and John Brown, Limited, Sheffield, when flooding occurred during the course of the same storm. The forge of F. J. Brindley and Sons (Sheffield), Limited, at their Pond Street works, was flooded to a depth of a foot and a well in the middle of the floor spouted water. At Rotherham, all the floor gratings at the works of Yates, Haywood and Company, Limited, ironfounders, were lifted off when water surged up from the main Kimberworth sewer which runs under the firm's buildings in Thames Street. Flooding took place throughout the fitting shop and men were taken off production work to combat the dangers of flooding.

LAST WEEK, when reminding members of the Institute of British Foundrymen about the forthcoming "National Works Visit Day," the date was wrongly quoted. This function will take place on Friday, October 8.

LOW PHOSPHORUS
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Winchester House, Old Broad Street
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ALLOYS & BRIQUETTES
N.F. METALS & ALLOYS
LIMESTONE
GANISTER
MOULDING SAND
REFRACTORIES

And at:—

BIRMINGHAM, 2. 39, Corporation St., Midland 3375/6
LIVERPOOL, 2. 13, Rumford St., Central 1558
GLASGOW, C.2. 93, Hope Street, Central 9969

NOTICE

Replies to Box Numbers to be addressed to "Foundry Trade Journal," 49, Wellington Street, London, W.C.2.

SITUATIONS WANTED

YOUNG ASSISTANT FOUNDRY MANAGER desires progressive post. Good class practical experience, technically trained.—Box YA701, FOUNDRY TRADE JOURNAL.

YOUNG Man (30) seeks interesting position. Apprenticeship patternshop, drawing office, full time technical college teaching experience, grammar school educated, first-class full Tech. Cert. City and Guilds foundry practice; at present reading metallurgy; A.M.I.B.F.—Box YM722, FOUNDRY TRADE JOURNAL.

FOREMAN-MANAGER (51), Grey Iron Foundry, seeks final change in Yorkshire area. Life-time experience, practical and technical, general engineering, jobbing, machine tool castings. Accustomed full control all foundry departments.—Box FM706, FOUNDRY TRADE JOURNAL.

MELTING SHOP SUPERVISOR (31), A.M.I.B.F., desires progressive appointment. Experienced in the control of basic electric arc furnace plant, producing wide range of carbon and alloy steel to rigid specification.—Box MS717, FOUNDRY TRADE JOURNAL.

FOUNDRY PLANNING ENGINEER (29) seeks position with a progressive company. Time served patternmaker, experienced in wood and also metal patterns, for continuous casting and modern sand slinger equipment. Educated to national certificate level in Mech. Engineering, with endorsements. Conversant with ratefixing and estimating costs for castings and pattern equipment. References available.—Box FP718, FOUNDRY TRADE JOURNAL.

EXECUTIVE FOUNDRY ENGINEER, with experience plant layouts, large contracts, design, sales and erection, desires appointment in keeping with capabilities.—Box EF714, FOUNDRY TRADE JOURNAL.

SITUATIONS VACANT

The engagement of persons answering these advertisements must be made through a Local Office of the Ministry of Labour or a Scheduled Employment Agency if the applicant is a man aged 18-64 *inclusive or a woman aged* 18-59 *inclusive unless he or she, or the employment, is excepted from the provisions of the Notification of Vacancies Order,* 1952.

JOBBING MOULDERS required, London shop; also CUPOLA FURNACEMAN.—Apply PLANT, MACHINERY & ACCESSORIES, LTD., 136/140, Bramley Road, W.10.

MECHANIC required, with experience of "B.M.M." moulding machines, to service an installation of 32 Turnover and Straight draw type machines in a South African Foundry.—Replies to Box MR685, FOUNDRY TRADE JOURNAL.

SALES OFFICE ESTIMATOR required for Steelfoundry.—Apply in writing, giving full details of experience, etc., Box SO643, FOUNDRY TRADE JOURNAL.

SITUATIONS VACANT—*contd.*

SALES REPRESENTATIVE required by Refractory Manufacturers for Birmingham area. Experience of foundry trade desirable. Please write in confidence, stating experience and remuneration required.—Box SR673, FOUNDRY TRADE JOURNAL.

LABORATORY.—ASSISTANT METALLURGIST, experienced in Mechanical Testing, Chemical Analysis, and Heat Treatment of Light Alloys.—Write particulars of age, experience, and salary required, to Box LA700, FOUNDRY TRADE JOURNAL.

FOREMAN MOULDER required for small partly mechanised Foundry, also plate and loose patterns, for firm engaged on Ranges, Grates and Engineering Castings, "Baxi" Patent Fires and Products. House will be found if required.—Apply in writing, stating full particulars, age, wage required, and experience. — RICHARD BAXENDALE & SONS, LTD., Ironfounders, Albert Street, Chorley, Lancs.

FOUNDRY MANAGER required by a well-known Company of Ironfounders in the Wolverhampton area, producing Grey Iron, High Duty and Light Alloy Castings.

The position calls for a man of considerable experience in mechanised, semi-mechanised and loose pattern knowledge, with a sound knowledge of sand control and foundry technology.

Applications from gentlemen with such qualifications only will be considered, which will be treated in strictest confidence, should contain full details of age, experience, and salary required.—Box RB707, FOUNDRY TRADE JOURNAL.

THE INDIAN IRON & STEEL CO., LTD., Calcutta, require a SENIOR SALES ENGINEER. Applicants should be between 35 and 42 years of age, and must have practical knowledge of both heavy and light iron foundries and experience in the sales organisation and business administration of such undertakings. 3½ years' agreement, with salary and terms in accordance with qualifications.—Apply, in writing only, to MARTIN BURN, LTD. (LONDON AGENCY), 71, Queen Street, London, E.C.4.

MOULDER for Iron Foundry in West London area. Good Flat available for suitable man.—Write in confidence, Box MF721, FOUNDRY TRADE JOURNAL.

METALLURGISTS and METALLURGICAL CHEMISTS required by large, non-ferrous Founders in South-East London. The posts vacant are related to work both in the Production and Research Divisions of the Metallurgical Laboratory. Applicants should have a degree in metallurgy or equivalent qualifications, or alternatively, have had experience of the type of work. Salaries will be in accordance with qualifications and experience.—Write, giving full particulars, to PERSONNEL MANAGER, J. Stone & Co. (Charlton), Ltd., Woolwich Road, Charlton, S.E.7.

METALLURGIST, with experience in casting technology, required for research, development and technical sales liaison work on magnesium alloys. Applicants should possess Hons. degree in Metallurgy or A.I.M., and a knowledge of French and German would be of advantage. Successful candidates will become eligible for entry to the Company's Contributory Pension Scheme.—Applications in writing, quoting FJSA19, together with age, qualifications and experience, to PERSONNEL OFFICER (STAFF), Magnesium Elektron, Ltd., P.O. Box No. 6, Clifton Junction, near Manchester.

SITUATIONS VACANT—*contd.*

SOUTH AFRICA.—Long established Firm of Machinery Merchants and Engineers' Representatives, with highest reputation and connections, require competent FOUNDRY ENGINEER, to take charge of Foundry Plant and Equipment Sales. Exceptional prospects, pension scheme, car, and good remuneration. Free passage. State full particulars experience, age, etc., to Box SA719, FOUNDRY TRADE JOURNAL.

CUPOLA OPERATOR required by Iron Foundry near seaside town in Essex. Steady permanent job with good wages. 5 tons daily, with assistance available. Living accommodation caravan can be shared with one other employee.—Apply CROWN CASTINGS, LTD., Hockley, Essex.

REPRESENTATIVE.—Good technical Sales Representative required by leading Foundry in North Midlands, producing wide range of grey and special irons. Applicants must have previous experience in this field and would be required to operate primarily in the Midlands and Black Country areas. Good salary. Car provided. Superannuation scheme.—Write PERSONNEL MANAGER, Box RG716, FOUNDRY TRADE JOURNAL.

FOUNDRY FOREMAN required by South Coast Iron Foundry. Able to take full charge of machine moulding. Write, giving full details of past experience, age, and salary required. Only fully experienced man, used to getting results, not afraid of hard work, and desirous of rapid advancement, need apply.—Box FF715, FOUNDRY TRADE JOURNAL.

PATTERNMAKER required, to take charge of small Pattern Shop attached to jobbing Foundry, S.W. London. Must be able to train apprentices. Accommodation available. Vacancy due to retirement. State experience, age, etc.—WIMBLEDON FOUNDRY CO., LTD., 93-97, Kingston Road, Wimbledon, S.W.19. Telephone: Liberty 2780.

TECHNICAL REPRESENTATIVE/FOUNDRY TECHNICIAN, with extensive experience all branches, seeking advancement in the field of Representation, will be pleased to hear from Founders, Founders' Suppliers and Equipment Manufacturers. Excellent connections throughout the industry.—Box TR713, FOUNDRY TRADE JOURNAL.

DRAUGHTSMEN required, preferably with experience of Gravity Dies, Pressure Dies or Plastic Moulds.—Apply JOHN DALE, LTD., London Colney, Herts.

IRON FOUNDRY SUPERVISION.

REQUIRED. — FOREMAN / SUPERINTENDENT for South Africa. Experienced in sand and cupola control and mechanised foundry operation. Excellent terms and conditions and good prospects for suitable man.—Full particulars, Box RF712, FOUNDRY TRADE JOURNAL.

FOUNDRY PLANT DRAUGHTSMAN required to fill vacancy in Methods Dept. of leading foundry in North Midlands. Some experience in design of foundry equipment desirable. Extremely good prospects for energetic young man, prepared to tackle a variety of subjects.—Write, giving age, experience, etc., to PERSONNEL MANAGER, Box FP711, FOUNDRY TRADE JOURNAL.

IRON FOUNDRY FOREMAN required for small Jobbing Foundry near Bournemouth.—Write, giving age, particulars of experience and salary required to Box IF710, FOUNDRY TRADE JOURNAL.